contents

DECLARATION

I do hereby declare that the present dissertation entitled ***"Impact of dredging on water quality and group diversity of marine zooplankton during construction and reclamation activities of new berths at Mormugao harbour"****, is an original research work carried out by me at National Institute of Oceanography, Dona Paula, Goa and that no part there of has been published or submitted in part or in full, for any other degree or diploma in any University or Institute.*

Dated : ***Snigdha***

Place : Bhopal

Forwarded by Co-Guide……

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Snigdha

List of Tables

List of Figures

List of Plates

INTRODUCTION

Earth, one of nine planets in the solar system, the only planet known to harbor life and the "home" of human beings. From space earth resembles a big blue marble with swirling white clouds floating above blue oceans. About 71% of earth's surface is covered by water, which is essential for life. The rest is land mostly in the form of continents that rise above the oceans.

The major oceans on Earth cover an area of about 361 million square km. In the deepest parts, the bottom lays more than 10,000m from the surface and the average depth is about 3700 meters. India has long coastline of 6700km. This coast has some of the finest harbours along the eastern and western margins. Mormugao Harbour (Plate 1) is one of the important ports along the west coast of India. A total of 11 berths with modern facilities are operational at the Mormugao Port. The harbour is subjected to tidal fluctuations that result in deposition of mud and sand in the navigational channel. Also since the harbour is situated at the mouth of one of the major rivers in Goa, large quantities of riverine sediments get settled at harbour mouth tilling the navigational channel. The river Zuari has a total length of 67 km and annual runoff of 9 km^3.

In order to maintain the berths as well as the approach channel to the desired depths and for berthing ships maintenance, dredging has to be carried out at regular intervals. In addition to this, modernization of births or construction of new births also demands dredging operations.

Plate-1 : Mormugao Harbour

What is Dredging?

Dredging is the process of removing material (sediment, debris, and organic matter) from the bottom of the water body and in terms of a port dredging it is done in order to make it deeper allowing for the commercial and recreational water traffic such as oil tankers, cargo ships, tour boats, ferries, and larger power vessels or sailboats.

Dredging of the harbour is required because of the constant easterly movement of sand along the coast and thus, across the harbour entrance. The amount of material moved and deposited is directly proportional to the severity of currents and wave conditions. This constant movement of masses of sand is termed as **Littoral Drift.**

Because of the sand incursion at the mouth of the harbour, it is essential that regular dredging efforts should be maintained to assure sufficient depth at the harbour entrance to permit the safe passage of vessels transiting the entrance. **Shoaling** conditions caused by littoral sand drift produce dangerous and unpredictable breaking wave formations at the harbour entrance. These breaking waves are extremely hazardous for incoming, and outgoing vessels and pose a particular danger to individuals walking on either of the jetties.

The dredgers operate in much the same manner as a common vacuum cleaner. A huge nozzle bearing a rotating cutter or series of water jets is lowered to the bottom where the sand is agitated into a "thick soup." The mixture is then sucked up by means of a 1200 horsepower diesel pump and discharged to a desired location through a sixteen-

inch diameter plastic pipe. Under ideal conditions, the dredge can move up to 1000 cubic yards of material per hour.

Plate 2: Dredging Activity

The dredging activities as well as river runoff give rise to suspension of sediments, which make the water column turbid. The turbidity arrests the light penetration in the water column and reduces the photosynthesis process. Besides this the dredging operations may have severe impact on the flora and fauna of the estuarine region.

General Faunal Classification in Marine Environment

The marine fauna is generally classified into two types, Pelagic and Benthic i.e.

Pelagic (living in the water column)

1. **Plankton** : float or drift in surface waters
2. **Nekton** : swimmers; move laterally and vertically

Benthic (living on the sea bottom)

1. **Epifauna** : at the surface
2. **Mobile** : crawl or swim
3. **Sessile** : attached
4. **Infauna** : within the sediment -- burrowers

What is PLANKTON?

The word plankton originates from the Greek meaning "Wandering". 'Plankton' as a term was first used by Victor Hensen (1887) for the aquatic communities of floating and drifting organisms that are carried primarily by movement of water current rather by their own swimming ability. While this is so, it must be remembered that, considering their small size, many plankton animals are strong swimmers and are capable of moving through relatively long distances over a period of time, particularly in a vertical direction. Plankton includes organisms of both plant and animal origin. The plant component of the plankton is called phytoplankton and the animal component is called as zooplankton. There is a third group that can absorb dissolved organic matter called saproplankton. The majority of phytoplankton belong to Chlorophyceae, Cyanophyceae and bacillariophyceae. Their unique ability to fix inorganic carbon to build up organic matter through primary production makes them very important in food web.

CLASSIFICATION

Irrespective of the fact, whether plankton belongs to plant or animal origin, it is divided into two groups.

1. Euplankton – All true plankton
2. Pseudoplankton - Dead plankton and nonliving debris

Zooplankton are characterized by their faunal diversity compared to phytoplankton and include arrays of animal organisms, varying in size from the microscopic protozoans of a few microns to some jelly fish with tentacles of several

meters. No single system of classification has been adopted universally. They have been classified into several groups by size (Cushing *et al* , 1958)

1. Ultraplankton : <5 µm
2. Nanoplankton : 5-60 µm
3. Microplankton : 1-500µm
4. Mesoplankton : 0.5 – 1.0 mm
5. Macroplankton : 1-10 mm
6. Megaplankton : 10 mm

The larger organisms (20-100mm) are called micronekton. Depending upon the size (Raymont, 1983), the zooplankton are divided into megaplankton, macroplankton, mesoplankton, microplankton and nanoplankton.

Ecological Classification :

I) On the basis of their habitat:

- Marine plankton : Haliplankton

  Brakishwater plankton : Hypalmyroplankton
- Freshwater plankton : Limnoplankton.

II) On the basis of length of planktonic life:

- Holoplankton (Permanent plankton; holo - entirely) : Those living as plankton during their entire life. e.g. Copepods, chaetognaths etc.
- Meroplankton (Temporary plankton; meros - mixed) : Those living as plankton during only a part of their life. e.g. Eggs and larval stages of fishes.

III) On the Basis of depth distribution:

1. Pleuston : Living at the surface of the sea, part of whose bodies project in to the air. Example – Physalia and velella
2. Neuston : Living in the uppermost part (few to 10mm) of the surface layer.
3. Epipelagic : Living between 0-200m
4. Mesopelagic : Living between about 200 and 1000 m in daytime
5. Bathypelagic : Living below 1000m

IV) On the basis of food habit:

- **Herbivores :** Those zooplankton feed on phytoplankton are called herbivores. Example - Copepods, shrimps
- **Carnivores :** Those zooplankton feed on other small zooplankton are called as Carnivores. Example - Chaetognaths, ctenophores, etc.
- **Omnivores :** Those zooplankton feed both on phytoplankton and zooplankton are called omnivores

(Gajbhiye,2002)

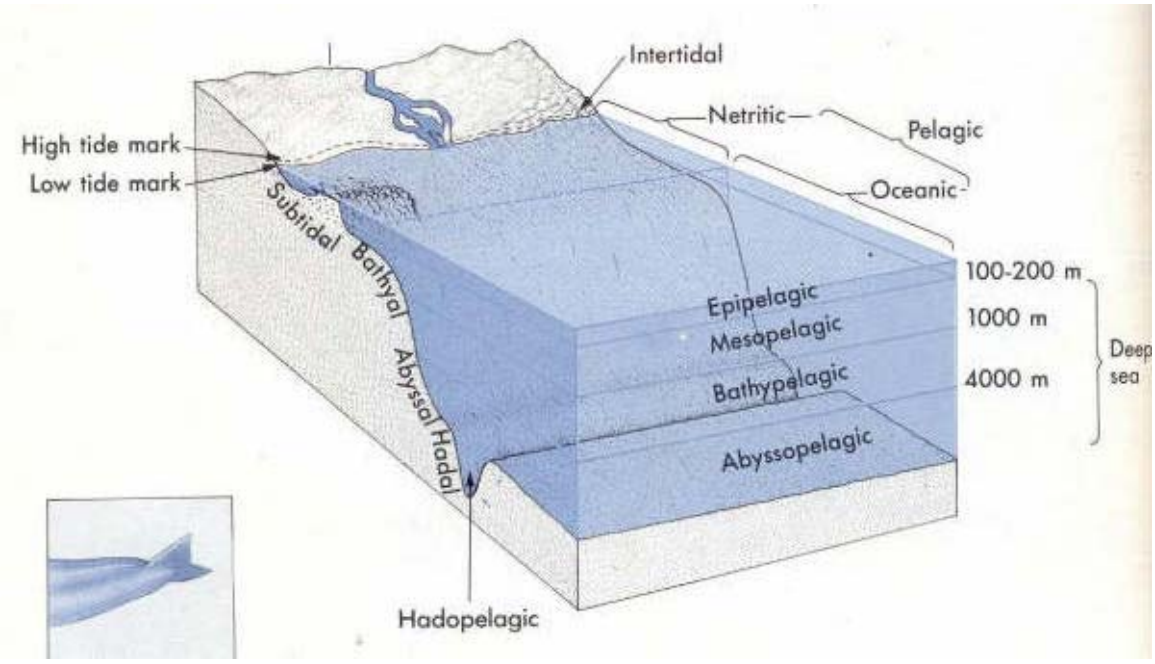

Plate 3 : Zonation of Marine Water

Some more about zooplankton

In an aquatic ecosystem zooplankton form an important link in the food chain from primary to tertiary level leading to the production of fishery. It has been well established that potentials of pelagic fishes viz. fin fishes, crustaceans, mollusks and marine mammals either directly or indirectly depend on zooplankton. By virtue of sheer abundance and intermediatary role between phytoplankton and fish, they are considered as the chief index of utilization of aquatic biotope at the secondary trophic level. The herbivorous zooplankton are efficient grazers of the phytoplankton and have been referred to as living machines transforming plant material into animal tissue. Hence they play an important role as the intermediaries for nutrients/energy transfer between primary and tertiary trophic levels. Due to their large density, shorter life span, drifting nature, high group/species diversity and different tolerance to the stress, they are being used as the indicator organisms for the physical, chemical and biological processes in the aquatic ecosystem (Gajbhiye,2002).

A} Ecological Significance Of Zooplankton

- **Vertical migration :**

Many groups of zooplankton such as Copepods, Amphipods, Euphausiids and Chaetognaths are known to make diurnal vertical migration. These migrations may extend to depth of several hundred meters and in some instances, even to 1000m or more, in which they undertake daily journey from the bottom to the surface at the approach of darkness and return to deeper waters at or before daybreak. Although light intensity is considered the prime factor for this phenomenon, other factors such as temperature, gravity pressure and predators are also known to influence this phenomenon.

- **Deep scattering layer :**

This phenomenon, otherwise called false bottom is related to vertical migration and is due to the large concentrations of particular zooplankton groups, such as *Siphonophores, Euphausiids*, etc. in specific depths. Such layer scatter sound beams and can be detected by sonic depth finding equipment. This layer rises and falls and increases with the available sunlight.

- **Bioluminescent zooplankton :**

A few species of Medusae, Ctenophores, siphonophores, Ostracods and Euphausiids are bioluminescent and are capable of emitting light. The light so produced acts as a warning signal to the predators of these organisms and also assists them in locating would be a predator.

B} Adaptation In Zooplankton

In the case of many of the zooplankton, which are incapable of active movement, buoyancy is achieved by means of morphological adaptations which increase frictional resistance. The increase in surface body area due to feather like projection or development of long spines or extreme flattening of the body helps the zooplanktons to float passively. In the case of medusae, siphonophores, ctenophores, tunicates, fish larvae etc.flotation is mainly archived by the inclusion of more fluids in the body, which reduces the specific gravity of a given volume of water. The buoyancy of other *Siphonophores*, such as Physalia, Velella and Porpita, is due to the presence of air filled organs, viz.,

pneumatophores. Flotation of the planktonic gastropod Janthina is facilitated by the foamy mucous substance secreted by it. The shell of Janthina and Petropod is very delicate and frigate and does not allow the animals to sink.

C} Ooze formation

The shell or tests of protozoan plankton, such a foraminiferan, radiolarians and gastropod molluscs, viz., pteropods, contribute to the formation of "globigerina ooze", radiolarian ooze, occurring over wide areas of the sea floor, might will be a resource material for thermal insulators and chromatographic columns.

D} Zooplankton as indicators

Many species of zooplankton are also known to be indicators of the specific water masses in which they are abundant. The arrow worms (chaetognatha), in particular *Sagitta elegans* and *S. setosa*, are known to, indicate the presence of mixed and unmixed waters in the North sea and the English channel respectively . The appearance as *S. elegans* in the North sea is always associated with the inflow of Atlantic water, resulting in good fishery. On the other hand, when *S. setoss* is present in the channel water, young fish are scarce .The association of Copepods, in particular Calanus species, with rich herring shoals is also worth mentioning. The abundance of krills of the species *Euphausia superba* helps fisher men in locating baleen whales ,seals and squids. This relationship is a direct one as krills constitute the basic food of baleen whales.

(Santhanam and Srinivasan, 1994)

FISH EGGS AND THE LARVA

- **Fish Eggs:**

Most offshore marine teleostean fishes have pelagic eggs ,which drift with the plankton in all water layers between the surface and the bottom .The chief exception among British species beings the herrings and the sand eels which have dermersal eggs ,and a small number of viviparous species.

Generally eggs are divided as –

1) Pelagic eggs

2) Demersal eggs

1. Pelagic eggs:

The pelagic eggs of most species are small in size, being between about 0.7mm and 1.5mm in diameter. A few species have large eggs between 1.6mm and 2.6mm in diameter .The size of eggs for all species varies, the egg of any one species tends to be smaller as its spawning period advances. All pelagic eggs are transparent and all are practically spherical. There is an outer egg membrane consisting of a double layer permeated by fine pores. The external surface of the egg membrane is smooth except in eggs such as those of callionyus in which there is an external rised hexagonal sculpturing.

The newly fertililsed egg usually floats with the oil globule upper most, the vegetative pole with the microphyte and the germ being the heavier. While the oil globule is at first movable over the surface of the yolk it tends to become fixed in position when the embryo is developing .

2. Demersal eggs:

The eggs, which are generally somewhat larger than planktonic eggs, may be laid in masses are sticky when first ejected. They thus tend to stick to any solid object or to one another.The eggs laid singly are also attached to rocks or inside the shells. The egg being larger, with more yolk than in planktonic eggs, development of the embryo within the egg is more prolonged and the larva usually hatches in a more advanced stage, with eyes pigmented.

❖ **Fish Larvae :**

In fishes, larval development is commonly, though not universally, divisible into

I) Pro larval

II) Post larval stages

Prolarvae are distinguished by the presence of the yolk sac and are commonly called sac fry by fish culturists. In some species, when the yolk sac disappears the little fishes is a diminutive adult, commonly called as an advanced fry by fish culturist In the early larva the yolk sac on the anterior ventral side of the body is a prominent feature and it often occupies about half of the total body length. In those with a short incubation period the eyes are not pigmented, the mouth is not functional and the anus is not open. During larval development the eyes become fully pigmented, and the mouth and the anus open. During development the content of the yolk sac and the oil globule, when present, are gradually used up. When the yolk is completely gone all the organs necessary for searching for and devoured its food are fully functional. The availability of the right food organisms at this stage is thus a critical factor . In the earliest post larval

stages a pigmentation pattern has usually appeared which is characteristic for the species. This pattern generally persists until the post larva assuming some meristic characters, after which pigmentation usually begins to become more diffuse or silvering occurs. The post larval period thus ends and the young fish ,now in the fry stage ,is capable of active swimming so ,that its strictly planktonic life is over.

Adverse effects of zooplankton on fishery potentials :

Although most of the species of zooplankton are helpful in fisheries ,a few are detrimental to the fishery potential .Certain zooplankton predators ,for example jelly fish, arrow worms and the Copepod *Euchaeta* may voraciously feed on fish larvae, decimating the fish population . It is also note worthy that water rich in jellyfish are invariable devoid of fish and hinder fishing operation by clogging the nets .In the case of herring, studies have shown an inverse relation between the fish and arrow worm and the pteropod *Limacina species.*

Economic importance of zooplankton :

In Arctic and Antarctic area where the euphausiid krill predominate, fishing of krill is a profitable venture. It has been suggested that krill may one day rival soybeans as a source of protein. The annual production of krill has been estimated at 200 million tons, which is more thane 2 times the world fish catch. However, the annual krill catch is presently only 20,000 tons. Hence there is a good scope for expanding fishing operation, particularly in the vicinity of krill rich grounds. Krill could be a good source for the large scale preparation of fish protein concentration (FPC),an easily digestible direct human food. Further more, it is also in corporate in poultry and other livestock feed. Certain species of

mysids are collected for food in the East Indies. Similarly, deep water Copepods, namely *Euchaeta nonvegeca* is a delicacy which one-day might support the fisheries for luxury markets. Although the collection of plankton as human food is not going to be a profitable venture except for Arctic and Antarctic krill, plankton from other latitude even though of less magnititude, is a potential resource for pharmaceutical.

Most of the commercially important pelagic fishes feed on zooplankton, hence, the study on prevalence and distribution of zooplankton is necessary in production potential of a given ecosystem. Investigations on zooplankton have been confined mainly to taxonomy, zoogeography, distribution pattern, community structure and trophic relationships. However, efforts are underway to integrate studies to biological and physical phenomena in the ocean.

Present work has been carried out to study the impact of dredging activities on the physico-chemical parameters at Mormugao harbour. This work forms the best of the studies undertaken by National Institute of oceanography to understand the impact of dredging in relation to construction of births 5A and 6A at the Mormugao harbour.

OBJECTIVE

The oceans are not just big buckets of water but a large and complex system of geological, physical, chemical and biological factors that have a decisive influence on the course of the terrestrial world, and thus also our lives. The oceans are perhaps the only habitat, large enough that we will not be able to change sufficiently to destroy it's functioning, although we seem intent on doing so, and on the land we almost certainly will.

Dredging and reclamation activities are not the permissible activities as per the environmental act. This is because this activity produces major harm to the pelagic and benthic organisms living in the marine ecosystems. But ports and harbours are often having encounters with siltation process and hence deepening of navigational channel and berthing area for ships is necessary.

Marine organisms are known to be adaptive in nature to the changes in environment but they have certain tolerance limit beyond which serious ecological damage could occur. However, limited work has been carried out so far on the effects of dredging on the pelagic organisms (Joseph *et al*, 1998) . These effects can vary depending on turbidity and the quality of sediments being dredged.

Hence the objective of the present work is to study:

"The impact of dredging on the physico-chemical characteristics of water and group diversity of Marine Zooplankton during construction and reclamation activities of new berths at Mormugao Harbour. "

LITERATURE REVIEW

Zooplankton are often an important link in the transfer of energy from producers to carnivores (Santhakumari and Peter, 1993). Zooplankton due to their large density, shorter life span, drifting nature, high group or species diversity and different tolerance to the stress, they are being used as a indicator organisms for the physical, chemical and biological process in the aquatic ecosystem (Gajbhiye, 2002). Padmawati and Goswami (1996) stated that the species richness and evenness were inversely related to the zooplankton biomass. Purushan *et al* (1974) observed that cladocera and meroplanktonic larva reached peak abundance in saline water mass. Madhupratap and Haridas (1975) noticed that displacement volume were higher at those stations where swarms of hydromedusae and ctenophores occurred. Achutankutty and Selvakumar (1979) observed the abundance of Acetes larvae during pre and post monmsoon in the estuarine system of Goa. Nair and Paulinose (1980) observed the abundance of decapod larvae near to the coast and a gradual decrease towards the open ocean. Unlike other zooplankton it is very difficult to obtain a accurate estimation of siphonophore population in an area because of its structure, complexities minuteness and tragile nature (Rengarajan 1983).

Rajgopal (1981) found that the zooplankton biomass in the entire area during monsoon was higher than the recorded pre and post monsoon.

The Arabian Sea is one of the most productive regions of the world oceans. This productivity mainly results from coastal and open ocean upwelling in summer and cooling effects during winter. It would seem that the meso-zooplankton abundance in the Arabian Sea is fairly high in the mixed layer all through the year. Most of the herbivorous

forms are either small filter feeders like copepods or large mucous filters feeders like tunicates.which are able to feed on very small particles. Nair *et al* (1999).

Chaturvedi, *et al* (1998) states that in the Arabian sea the pigment distribution reflects the introduction of nutrients into the photic zone. The maximum annual pigments biomass in the Arabian Sea occurs when the mixed layer is relatively shallow. Therefore, at the time of sufficiently shallow MLD and less turbulent conditions the pigment and temperature pattern show covariation. Marine phytoplankton are a major sink for atmospheric CO_2 they have a decisive role in future trends of carbon dioxide concentrations in the atmosphere as well as in terrestrial and aquatic ecosystems [Bowes, 1993; Melillo *et al* , 1993]. Phytoplankton are the basis for the intricate marine food webs; thus, any losses in biomass production necessarily cause decreases in biomass at the next higher trophic levels. Eventually these losses are relayed through all levels of the food web, ultimately leading to losses in fisheries yield [Nixon, 1988; Gucinski *et al* , 1990]. Marine organisms living at all trophic levels above the primary producers excrete dissolved nutrients into the water that are ideally suited to fertilizing the phytoplankton. Very often this is ammonia, which all fish excrete from their gills. This has sometimes been recognized in the literature as a significant route of nutrient regeneration in surface water, but usually only the contribution of the zooplankton has been acknowledged. Recently a "microbial loop" dynamic has been appreciated in marine food webs, one effect of which is the regeneration of nutrients into the photic zone. (Nybakken, 1997)

The number of fish larvae and salinity showed a significant negative correlation ($p<0.001$) indicating that their number decreased as salinity increased (Devi, 1977).

The number of fish larvae and dissolved oxygen content also showed a negative correlation ($p<0.001$) suggesting that the number decreased as oxygen value (Devi, 1977). In tropical embayments and estuaries in India, accelerated zooplankton production during periods of high salinity was documented by Madhupratap (1986) and Tiwari & Nair (1993).

Dissolved oxygen values showed that the surface layers were well oxygenated through out the year also suggested that low values of surface temperature were noticed in July and August (Stephen, 1977). Zooplankton diversity was inversely related to abundance, which was generally higher during the SE monsoon period as compared to the NE Monsoon (Mwaluma *et al*, 2003)

The tuna that constitutes a major oceanic pelagic fishery is widely distributed in the tropical and subtropical regions of the world oceans also stated that the capture of tuna fish larvae during all seasons of the year would suggest that the spawning is continuous throughout the year (Peter, 1977).

Hydromedusae represent an important ecological zooplankton category because of their position as exclusive carnivores also mentioned that coastal zones of India are completely richer in hydromedusae(Santhakumari, 1977).

Gajbhiye *et al* (1984) observed that environmental parameters like salinity, dissolved oxygen, BOD and nutrients directly influence the abundance and diversity of zooplankton. Rajagopal (1981) studied the close association between salinity changes in the environment and abundance of zooplankton. Spatial and temporal distribution of zooplankton in relation to salinity showed their preferences to specific salinity regimes in

the Vashishtha- Godavari estuary and in other Indian estuaries. (Madhupratap, 1987). Salinity is attributed as an important factor regulating distribution of copepods species in nearshore areas (Huang and Zheng, 1987; Lindo,1991; Mallin, 1991; Kouwenberg, 1994). Nasser *et al* (1998) observed that the environmental parameters such as water temperature, salinity, cloud cover, wind force, rainfall and tide influence the distribution and abundance of zooplankton. Mustafa *et al* (1999) noticed that saltpans sustain a fairly rich zooplankton standing stock with low diversity. Factors such as salinity, temperature, currents, suitable food , availability, breeding seasons of the parental stock etc. regulate the distribution of medusa during different seasons of the year (Santhakumari and Nair, 1999). Vareethiah (1999) observed no significant interaction between seasons and stations regard to salinity. According to Santhakumari *et al* (1999), the zooplankton species, which occur during high saline period, tolerate wide salinity fluctuations.

Cushing (1971) suggested that the levels of nutrients and primary and secondary productivity ultimately determine the sustainable harvest of fish resources. Ecological observations on the marine zooplankton communities are important in accessing health of the coastal waters (Youngbluth, 1976); Lindo, 1991; Mallin, 1991; Buskey, 1993; Kouwenburg, 1994) hence they are considered to be the ecological indicators of water bodies. The waters along the West Coast of India are rich in zooplankton production (Menon and George, 1977).

Copepods dominate the marine zooplankton community and often contribute over 80 – 90% of the total zooplankton count in near shore and estuarine habitat (Ramaiah and Nair, 1993). Copepods as the major herbivore community 76%-83% to total zooplankton population. Decapods were relatively more in the outer

(average 11%) as compared to interior zone (average 7%) (Nair *et al*, 1999). The sub class copepods consists of 10 orders and exhibit great diversity in morphology as well as the habitats they occupy within the orders themselves, there are sometimes overlaps, some are free living or could be parasitic. There are approximately 11500 known species in this subclass.(Madhupratap,1999). Better fed copepods produce larger batches of eggs. (Steidinger and Walker, 1984) Therefore, the successful reproduction of these 'herbivorous' zooplankton depends not only on an adequate supply of phytoplankton, but also on an sufficient supply of appropriately sized 'animal' food. Phytoplankton functions best, it seems, only as 'baby food' for many zooplankton species, therefore a vigorous population growth cannot be expected if that is the only food that is provided in abundance. The density of an organism depends upon the availability of the suitable food material (Santhakumari *et al*, 1999).

Siphonophora are the major and regular constituents of the marine zooplankton, which occupy fourth or fifth place in the order of abundance in the tropical community (Yamazi, 1971).

The fish eggs and larvae occurrence during summer indicates the spawning periods of the various fishes of the inshore waters of the Tuticorin (Marychamy *et al*, 1985). The predators having the greatest impact on (pelagic) fish eggs and larvae are probably schooling (pelagic) juvenile and adult fish…Much of this predation is on newly spawned eggs as they are released and still highly concentrated. While these predators are general filter feeders, they seem to be attracted to spawning sites specifically for the purpose of feeding…Planktivorous fish are known to be important predators of fish eggs and larvae, and a large school may well eliminate a patch of fish eggs or larvae…"(Steidinger and Walker, 1984)

Effective biological fertilization of the sea involves not only making nutrients available in surface waters to stimulate phytoplankton growth, but also the simultaneous nourishing of a variety of carnivorous consumers, since their sustenance is essential to the repopulation of their juveniles, the essential herbivores. This is what the fish egg appears to have been designed to do. (MacKenzie, 2002)

When examined from the point of view of its utility in "ocean fertilization," the fish egg appears to be a particularly clever device. First of all, most fish eggs float. This physical movement shifts protein dense material upwards through the water column, acting to partly compensate for the surface-depleting effect of sinking organic material. A biological "upwelling" therefore also occurs. (MacKenzie, 2002)

Once they are positioned within the upper layers of the water, a high proportion of fish eggs are eaten before they hatch. The fish egg is virtually defenseless against its predators, and due to its high protein and energy content, probably represents the most nutritionally valuable food item available in the plankton. The eggs that are not consumed will, after a short while, hatch and transform themselves into tiny fish larvae. During the time (days to weeks to months) that it must live in the plankton, the larva feeds on edible matter that is smaller than itself, accumulating nutrients and energy within its body while slowly and continuously releasing an appropriate dosage of fertilizer for the phytoplankton. As it grows, the fish larva presents itself as a feeding option to a range of ever larger carnivores. Sustaining these carnivores allows those species to continue to live and reproduce, to cycle nutrients back to the phytoplankton, and to feed their own consumers. (MacKenzie, 2002)

So the fish egg can be appreciated as a cleverly designed and important biological ocean fertilization device. If it is not consumed in its original presentation, it will

automatically transform itself into a slightly different food item that is suitable for an ever-increasing size range of predator. In effect, then, the fish egg can be seen to provide fertilizer not only to phytoplankton and zooplankton, etc. (and most of the food value is extracted at these lower levels), but also a rippling fertilizing effect that is ultimately felt throughout the entire web. (MacKenzie, 2002).

Coastal regions adjacent to estuaries present favorable conditions for the development of fish species that use these areas as nursery and protection for their eggs and larvae (Soares *et al,* 1991). The partial overlap between the distribution of zooplankton biovolume and fish eggs suggests a synchrony between spawning and food availability for the future larvae. This synchrony between ichthyo and zooplankton has already been observed by Katsuragawa *et al* (1993).

Due to the importance of the interaction between physical and biological processes, specific studies on spawning and life cycle of fish larvae have been recommended for a better understanding of recruitment variability in fisheries resources (Hunter & Alheit, 1997), and for an enhancement in the knowledge of life cycles of fish species through the determination of their spawning location and period (Hempel, 1973).

There was not much variation in the temperature of the water column. Temperature & Salinity were homogenous throughout the study area (Straits of Malacca) and the changes were significant only during periods of heavy rains.(Rezai *et al* ,2003). The fish eggs and larval occurrence during summer indicates the spawning periods of various fishes of the inshore waters of Tuticorin (Marychamy *et al*, 1985).

The water current of the sea also may contribute significantly to the abundance of fish during premonsoon (Krishnamurthy, 1964). Paulinose *et al* (1998) found the pre monsoon period showing a comparable trend with higher standing stock of zooplankton

stock during flood period in the creek than ebb period. According to Devi (1993) the eggs and larva were to occur in the Cochin Backwaters during the pre monsoon period but not during the southwest monsoon period. During the southwest monsoon period larva belonging to very early stage were found at the marine end.

There has been considerable investigation in recent years of dumping areas receiving dredge spoils. The effects of the disposal of such wastes include the physical blanketing of the bottom (Norton, 1978).

MATERIALS AND METHODS

Description of Study Area :

Mormugao Harbour is situated in the state of Goa at Lat. 15^0 25' N and Long. 73^0 47' E. It is a semi natural port located on the southern bank of the river Zuari mouth adjoining the Arabian Sea with back water on the west side.

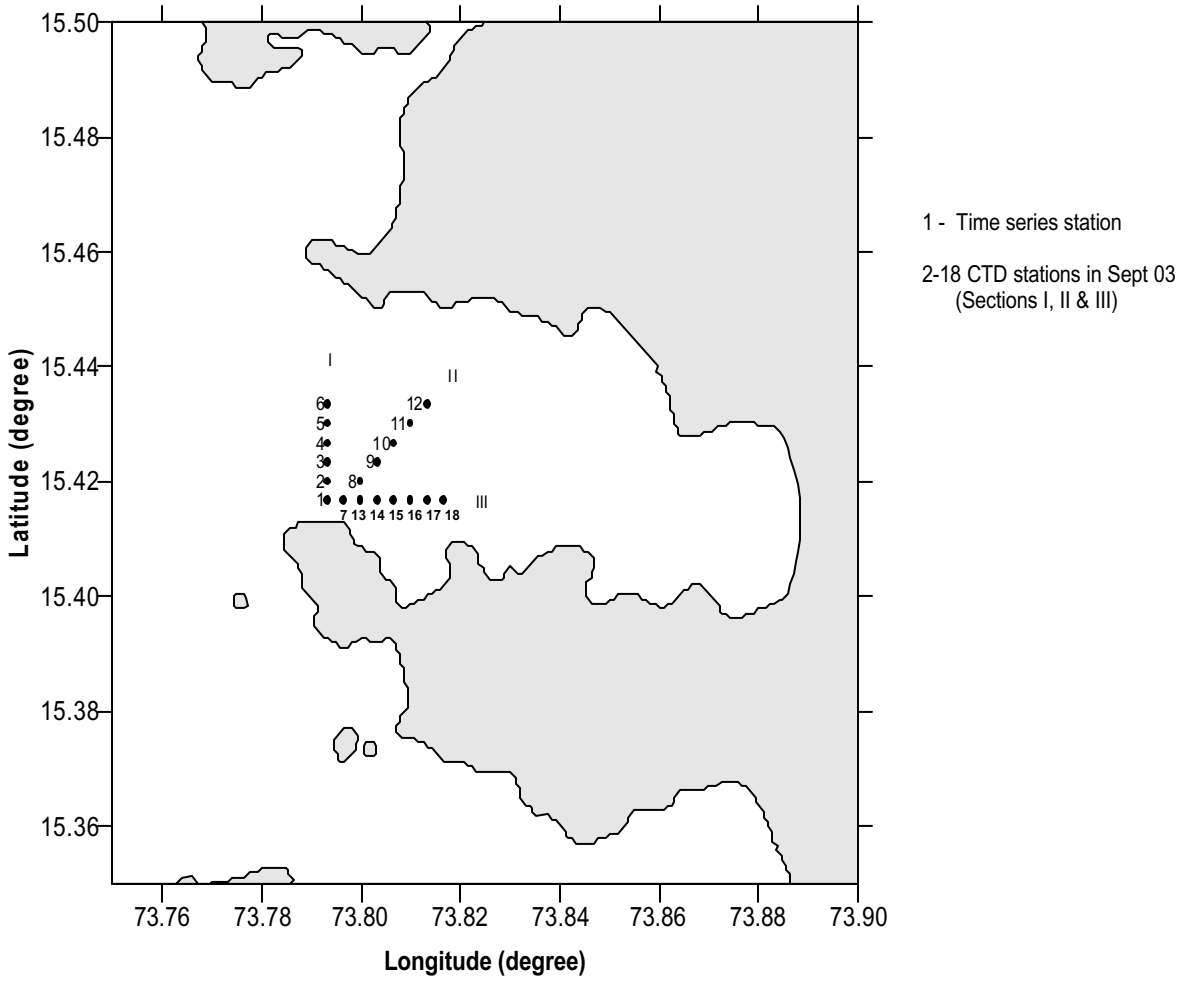

Fig. 1 : Location of the Study Area

Work Strategy :

In order to understand the impact of dredging on the occurrence of zooplankton, following physicochemical and biological observations were planned. Physical observations included vertical profile of temperature and salinity using CTD profile. Water quality parameters studied included pH, dissolved oxygen (DO); nutrients such as nitrate (NO_3), nitrite (NO_2). The biological parameters included chlorophyll and zooplankton biomass and density.

Field Study :

The detailed field studies involved collection of the surface and bottom water samples at nine stations along 3 different transects covering Mormugao Bay in order to trace the movement of sediments. The transects chosen were in 3 different directions from the dredging site as follows:

- First transect along the side of the harbour
- Across the mouth of River Zuari
- At oblique angle between these transects.

SAMPLING :

High and low tide sampling :

Along these transacts the sampling was carried out at two tidal cycles of high and low tides for various chemical and biological parameters in order to understand the influence of tides on various parameters. But sediment sampling was done only once a month.

Diurnal sampling :

Tide is one of the important physical factors governing the environmental features of an estuary. Hence it is essential to obtain information on the range of variation of some of the environmental parameters with the tidal rhythm. In an aquatic system the sediments act as a storage reservoir of these nutrients. In times of need and their constant removal from water column, sediments greatly help in replenishing the nutrients and maintaining the biological cycle of the system. Such an exchange depends on the characteristics of sediments and hydrographic features of the coastal waters.

In order to understand the changes occurring during the 24-hour period a diurnal sampling at single station was carried out for chemical and biological parameters. The diurnal station was chosen at a distance within 300 meters of the construction site and monitored at every 2-hour interval.

The dredging activities which commenced in September 2003, continued up to May 2004.

Sampling stations were fixed using Global Positioning System (GPS) Model "Garmin GPS-12", USA. The methodology for collection and analysis of the data and the results obtained are described below:

DETAILED METHODOLOGY:

(A) CTD (Conductivity - Temperature- Depth) profiler (Plate 4) :

A portable CTD system, the SBE 19plus bearing Sr. No 4167, has been utilised to obtain vertical profiles of temperature and salinity at different locations. This insitu profiler samples the water parameters at the rate of 4 scans/second. Conductivity (a measure of salinity) and temperature frequencies are multiplexed through a precision Wein Bridge. Pressure is acquired with 1:7000 resolution through an A/D converter. The profiler is lowered into water to collect the data and after recovery it is connected to the computer to transfer the stored data into the hard disc of the computer for further calculations. The profiler consists of an internal field glass conductivity cell with platinum electrodes, pressure-protected thermistor temperature sensor and a mechanical strain gauge pressure sensor (semi-conductor type). Four single-ended 12 bit A/D input channel and +5 volt /50 ma output power for optional auxiliary sensors are included. The titanium housing contains 9 "D" size alkaline cells and is rated for 600 m operating depth. Battery life is about 60 hr. 8 MB of flash RAM memory are available when recording conductivity, temperature and pressure at 4 scans/sec. The CTD profiler communicates directly with the computer via a standard RS-232 interface.

Plate : 4 CTD (Conductivity - Temperature- Depth) profiler

(B) Chemical parameters :

1) Turbidity :

The turbidity of water was determined by Nephlometric method using Cyberscan Turbidometer TB 1000, Eutech Instruments, Singapore. The results are expressed in Nephlometric Turbidity Units (NTU). The method is based on comparison of intensity of light scattered by a standard reference suspension under same conditions. The greater the intensity of the scattered light, the higher is the turbidity. Standard turbidity suspensions for calibration were prepared using hydrazine sulphate and hexamethyline tetramine and the analysis was carried out using turbidometer.

2) Suspended sediment concentration :

Water samples were collected at 2 different depths i.e. near surface and near bottom using a 5-liter Niskin Water Sampler **(Plate 5)** to estimate suspended load. The Niskin Water Sampler has a closing mechanism to collect the sub surface water samples at the desired depth. Known quantity of water was filtered through pre-weighed 0.45 µm Millipore membrane filter papers. After filtration these filter papers were dried, weighed and the differences (between the prefiltration and posfiltration) were computed to estimate the quantity of suspended sediments present in the collected water sample.

FIELD WORK

Plate 5 : Collection of Water Samples By NISKIN WATER SAMPLER

3) pH :

pH was measured immediately after collection of the water sample using Lab India pH analyzer after standardizing with standard pH buffers.

4) Dissolved Oxygen (DO) :

Winkler's method was used for the determination of dissolved oxygen by fixing a measured volume of water sample immediately after collection with reagents Winkler A and Winkler B. Standard iodometric titration was adopted for the analysis purpose.

5) – Nutrients :

I- Nitrite-Nitrogen (NO_2-N) :

The nitrite in water sample was diazotised with sulphanilamide and coupled with N-1-Napthyl ethylene diamine dihydrochloride. The absorbance of the resultant azo-dye was measured at 543 nm.

II - Nitrate- Nitrogen (NO_3-N):

Nitrate in seawater sample was first reduced to nitrite by heterogeneous reduction by passing the buffered samples through an amalgamated cadmium column and the resultant nitrite was determined as above. The measured absorbance was due to initial

nitrite in the sample and nitrite obtained after reduction of nitrate. Necessary correction was therefore made for any nitrite initially present in the sample.

III- Phosphate- Phosphorus (PO_4- P):

For the determination of inorganic phosphate, the samples were made to react with acidified molybdate reagent and then reduced using ascorbic acid. The absorbance of the resultant phospho-molybdate blue complex was measured at 880 nm.

(C) Biological parameters

Chlorophyll *a*:

For the estimation of chlorophyll *a*, 500ml of water sample was filtered through GF/F glass fibre filter paper and extracted in 90% acetone overnight. The extracts were used for the estimation of fluorescence before and after acidification using Turner Designs Fluorometer **(Plate 7 & 8)**. The fluorescence values were converted to chlorophyll *a* and phaeophytin using appropriate calibration factor. All the analysis were carried out as per procedure described in Parsons *et al*, (1984).

Plate 7 : Turner Designs Fluorometer

Plate 8 : Chlorophyll Analysis

Collection of Zooplankton :

Zooplankton samples were collected with the help of a fishing trawler by surface tow for 5 minutes with the speed of 1.5 Knots. The zooplankton net used was Heron-Tranter net **(Plate 6)** of 200 µm mesh size, having a rectangular mouth of area 0.25m^2. The volume of the water filtered through the net was recorded by the calibrated flow meter attached to the net during the tow. The samples thus collected, were fixed and preserved in 5% formaldehyde solution.

These samples were further brought to the Biological Oceanography Division, National Institute of Oceanography Division, Dona Paula, Goa for further laboratory work.

Estimation of Biomass :

The zooplankton biomass was estimated by displacement volume method. In this method, first a known volume of filtered seawater was taken in a 100 ml measuring cylinder. After removing moisture from the zooplankton sample, it is added in that known quantity of the seawater in that 100 ml measuring cylinder. The difference between the final and initial volume of the water in the cylinder was considered as the zooplankton biomass. These biomass values were expressed in ml/100m^3.

Splitting :

It is always very difficult to analyse the full zooplankton samples due to their huge quantity so after measuring biomass these zooplankton samples were split into 6.25% using the 'Folsom Plankton Splitter' **(Plate 9 & 10)** for convenient analysis.

FIELD WORK

Plate 6 : Heron Trantor Net

Plate 9: Folsom Splitter

Plate 10: Splitting the samples

Qualitative analysis and data processing :

Most of the times, 6.25% of the sample was taken. For quantitative analysis of these zooplankton samples Olympus Research Stereoscopic Microscope **(Plate no 11 & 14)**, Bogorov's Chamber **(Plate 12)** and needle **(Plate no 13)** were used.

The number of individuals in each group was counted from sub-sample and computed to the whole sample .The number of individuals per unit volume was calculated. The numerical abundance of different groups was expressed in terms of number/100m^3.After counting the zooplankton population for each sector, its average and standard deviation was calculated. The percentage composition of the various zooplanktonic groups was calculated

Plate 11: Olympus Research Stereoscopic Microscope

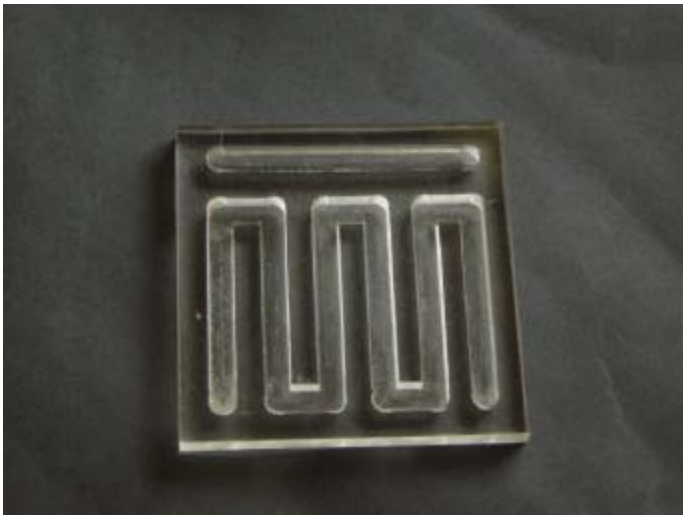

Plate 12 : Bogorov's Chamber

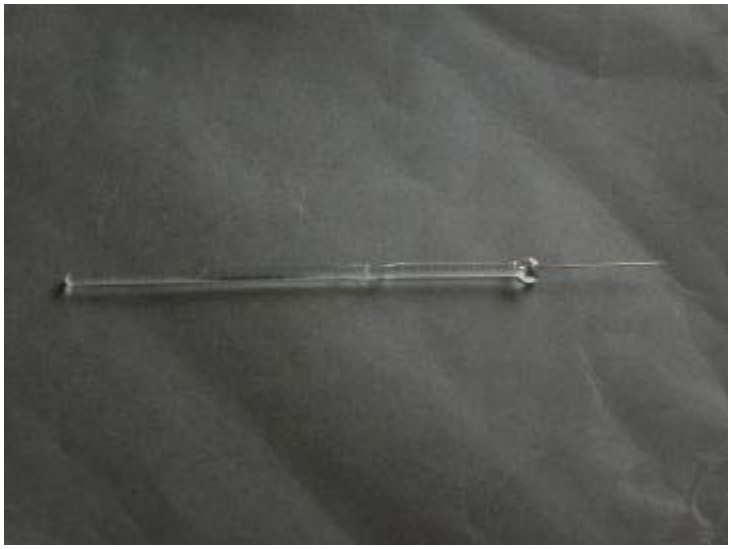

Plate 13: Needle

Plate 14 : Analysing the samples

RESULTS AND OBSERVATIONS

The following variations were found in different environmental parameters recorded during the study period at Mormugao Port.

Tides :

The tidal heights during the sampling period on 19th and 20th May 2004 ranged from 0.14 to 2.06m. (Fig:1)

Salinity :

Vertical profile of salinity during high tide in May showed that the values were almost homogeneous at different depths upto 10m. In the surface waters, the salinity ranged from 34.02 to 35.35 PSU during high tide and from 34.44 to 35.43 PSU during low tide. While in the 10m-water column the salinity ranged from 34.02 to 35.44 PSU during high tide and from 34.44 to 35.53 PSU during low tide. At the diurnal station the surface salinity ranged from 34.13 to 35.44 PSU and in the water column the values varied from 34.13 to 35.46 PSU. During May the variation in the salinity was in a narrow range during different tidal observations. On the other hand, the variation in salinity was large in June with surface values ranging from 19.32 to 22.62 PSU, whereas at 5m depths the values ranged from 24013 to 32 PSU. Vertical profile indicated increased salinity trend from surface to bottom. This is mainly because of monsoon precipitations. The fresh water from land runoff flows over the saline water tongue that enters the estuary during the flood tide from bottom. Mixing of saline waters with the estuarine water gives rise to a strong vertical gradient in salinity, where as in premonsoon the salinity remains vertically homogeneous.

Sampling Details		Min	Max	Mean	St. Dev	n
May HT	**Surface**	34.02	35.35	35.01889	0.472373	9
	Bottom	34.24	35.43	35.3567	0.05895	9
LT	**Surface**	34.44	35.43	35.1489	0.35197	9
	Bottom	35.27	35.44	35.3622	0.05995	9
Diurnal	**Surface**	34.97	35.5	35.307	0.19494	10
	Bottom	29.39	35.72	34.449	1.86469	10
June	**Surface**	19.32	22.62	21.1738	0.99274	9
	Bottom	24.13	32	29.3438	2.57802	9

(n* – number of values)

Table 1-: Range and Average of Salinity during different sampling periods

Temperature :

In the month of May, the surface water temperature ranged from 30.16 to 30.55 ^{0}C during flood tide and from 30.27 to 30.79 ^{0}C during ebb tide observation. Vertical profiles of temperature at different depths showed almost similar values indicating well-mixed conditions in the estuary. During diurnal observations surface temperature ranged from 30.2 to 30.71 ^{0}C.

Sampling Details		Min	Max	Mean	St. Dev	n
May HT	**Surface**	30.16	30.55	30.33	0.14	9
	Bottom	30.19	30.43	30.31	0.07	9
LT	**Surface**	30.27	30.83	30.63	0.18	9
	Bottom	30.34	30.78	30.61	0.13	9
Diurnal	**Surface**	30.4	31.8	30.90	0.48	10
	Bottom	30.5	31.2	30.73	0.30	10
June	**Surface**	28.36	29.06	28.63	0.21	9
	Bottom	28.47	28.59	28.54	0.04	9

(n* – number of values)

Table 2 : Range and Average of Temperature during different sampling periods

Not much difference was observed during day and night time temperatures at surface and in the water column. In June the temperature remained much below than the May observations, with surface values ranging from 28.36 to 29.06 ^{0}C. The vertical profiles showed not much difference indicating well mixed conditions in water column during monsoon also. Goswami, *et al* (1979) also observed lower temperature and salinity during their observation in Zuari estuary.

Turbidity :

Turbidity which is responsible for arresting the penetration of sunlight in water column ranged from 23.9 to 68.9 (avg. 39.74) NTU in surface waters during high tide and from 7.55 to 29.7 (Average 16.73) NTU during low tide. In the bottom waters the turbidity showed similar changes, as in surface. The tidal observations showed that turbidity remained much lower during low tide indicating the input of suspended matter from estuarine origin in low during May. The diurnal observation near the construction side showed surface turbidity to range from 12.4 to 29.6 (Average 16.75) NTU.

Sampling Details		Min	Max	Mean	St. Dev	n
May HT	Surface	23.90	68.80	39.74	15.02	9
	Bottom	7.90	68.10	37.99	19.01	9
LT	Surface	7.55	29.70	16.73	6.63	9
	Bottom	8.90	18.50	13.21	3.14	9
Diurnal	Surface	12.40	29.60	16.75	5.76	10
	Bottom	12.80	59.20	25.18	14.29	10
June	Surface	7.38	13.4	11.06	2.00	9
	Bottom	10.3	63.5	29.57	20.02	9

(n* – number of values)

Table 3 : Range and Average of Turbidity during different sampling periods

Compared to May observations surface turbidity remained lower in June. However, the bottom values fluctuated largely ranging from 10.3 to 63.5 NTU which is mainly associated with river run off. Joseph *et al* (1998) observed that the conditions after and predredging at the dredging site were much different fom each other. As the surge in the nutrients was confined only to the end stage of the dredging, the possibility of any extensive water quality deterioration at the site and in its vicinity was remote.

Suspended Sediments :

The suspended sediments in May ranged from 0.035 to 0.146 (average 0.06) g/l in surface waters during high tide and from 0.034 to 0.069 (average 0.05) g/l during low tide. The suspended sediments were much higher in the bottom waters during the second tidal observations.. During diurnal observation suspended sediments showed limited changes in values ranging from 0.034 to 0.045 (average 0.04) g/l in surface waters with average values remaining lower than the transect stations. This suggests that the suspended sediments load near the dredging and construction site was much lower than the other sampling locations in the estuary.

Sampling Details		Min	Max	Mean	St Dev	n
May HT	**Surface**	0.035	0.15	0.063	0.038	7
	Bottom	0.038	0.07	0.081	0.063	7
LT	**Surface**	0.041	0.07	0.057	0.007	6
	Bottom	0.034	0.10	0.059	0.021	6
Diurnal	**Surface**	0.034	0.05	0.039	0.005	7
	Bottom	0.032	0.05	0.040	0.005	7
June	**Surface**	0.028	0.04	0.034	0.005	7
	Bottom	0.049	0.06	0.088	0.073	7

(n* – number of values)

Table 4: Range and Average of Suspended sediments during different sampling periods

pH :

In the surface waters, pH fluctuated within a narrow limit of 7.84 to 8.01 (average 7.93) during flood tide. The pH remained much lower during ebb tide ranging from 7.79 to 7.95 (average 7.87) as compared to flood tide. No consistency was observed between surface and bottom waters in pH distribution although at certain locations homogeneous values prevailed. However, the values at diurnal station were almost similar in surface and bottom waters.

In June the pH ranged from 7.8 to 8.37 in surface and bottom waters which were similar to the observation in May.

Sampling Details		Min	Max	Mean	St Dev	n
HT	**Surface**	7.84	8.01	7.93	0.06	9
	Bottom	7.76	8.14	7.91	0.11	9
LT	**Surface**	7.79	7.95	7.87	0.07	9
	Bottom	7.79	7.97	7.89	0.07	9
Diurnal	**Surface**	7.99	7.69	7.84	0.09	10
	Bottom	7.79	7.95	7.88	0.06	10
June	**Surface**	7.9	8.37	8.10	0.17	7
	Bottom	7.82	8.15	7.95	0.12	7

(n* – number of values)

Table 5: Range and Average of pH during different sampling periods:

Dissolved Oxygen (DO) :

In the surface waters DO ranged from 4.88 to 5.31 (average 5.11) mg/l during high tide. The values were almost similar in the bottom waters indicating well-aerated

conditions in the estuary. DO remained somewhat higher during ebb tide indicating its input from estuarine origin. The diurnal stations showed lower DO as compared to the transect stations. Which may be due to bacterial consumption or oxidation of dredged sediments.

In June DO remained much higher than May ranging from 7.13 to 8.22 (average 7.72) mg/l. in surface waters, which may be due to the influence of fresh water. The lower values observed at certain locations on bottom water may be associated with offshore saline upwelled water.

Sampling Details		Min	Max	Mean	St Dev	n
HT	**Surface**	4.88	5.31	5.11	0.15	9
	Bottom	4.68	5.46	5.09	0.24	9
LT	**Surface**	5.01	6.06	5.45	0.33	9
	Bottom	4.9	5.78	5.43	0.35	9
Diurnal	**Surface**	4.63	5.07	4.96	0.14	10
	Bottom	4.28	5.04	4.79	0.24	9
June	**Surface**	7.13	8.22	7.72	0.32	9
	Bottom	3.14	8.1	5.58	2.04	9

(n* – number of values)

Table 6 : Range and Average of DO during different sampling periods

Nutrients :

Nitrite(NO_2) :

At most of the stations nitrite remained low, with similar values in the bottom during high tide observations, except at station 16. But the station wise variation in NO2 was much higher during low tide. At the diurnal stations, nitrite remained much higher

ranging from 0.31 to 1.24 µ mole/l between surface and bottom waters. In June nitrite showed similar values as that in May ranging from 0.17 to 1.14 µ mole/l between surface and bottom waters.

Sampling Details		Min	Max	Mean	St Dev	n
HT	**Surface**	0.21	1.07	0.41	0.26	9
	Bottom	0.19	0.46	0.32	0.09	9
LT	**Surface**	0.29	0.76	0.46	0.14	9
	Bottom	0.27	0.71	0.45	0.14	9
Diurnal	**Surface**	0.31	0.82	0.53	0.27	10
	Bottom	0.36	1.24	0.70	0.26	10
June	**Surface**	0.19	0.68	0.38	0.16	9
	Bottom	0.17	1.14	0.50	0.28	9

(n* – number of values)

Table 7 : Range and Average of Nitrite during different sampling periods

Nitrate (NO_3) :

The value of Nitrate at surface ranged from 1.09 to 6.2 µ mol/l and at bottom it ranged from 1.84 to .32 µ mol/l during High tide. During Low tide the NO_3 value varied between 0.51 and 3.9 µ mol/l at surface and 1.47-3.16 µ mol/l at bottom. In diurnal sampling the value recorded ranged from 1.65 to 6.2 µ mol/l at surface and 2.00-8.96 µ mol/l at bottom. In June the minimum NO_3 value at surface and bottom were absent but the maximum NO_3 values at surface and bottom were accounted as 0.48 and 3.68 µ mol/l respectively. The highest value (8.96 µ mol/l) of Nitrate was recorded at bottom in diurnal sampling.

Sampling Details		Min	Max	Mean	St Dev	n
HT	**Surface**	1.09	6.2	4.087778	1.958748	9
	Bottom	1.84	6.32	4.181111	1.639493	9
LT	**Surface**	0.51	3.9	2.0625	1.093196	9
	Bottom	1.47	3.16	2.14	0.610574	9
Diurnal	**Surface**	1.65	6.2	4.493	1.331449	10
	Bottom	2	8.96	4.488	1.998081	10
June	**Surface**	0	0.48	0.110236	0.159088	4
	Bottom	0	3.68	1.284444	1.299155	6

(n* – number of values)

Table 8 : Range and Average of Nitrate during different sampling periods

Phosphate (PO_4) :

Levels of phosphate in the water column showed large fluctuations along the transect stations during both the tidal observations with surface values varying from 0.53 to 2.01 µ mole/l during high tide. Higher values observed in bottom may be due to the desorption from bottom sediments.

Sampling Details		Min	Max	Mean	St Dev	n
HT	**Surface**	0.53	2.01	1.29	0.50	9
	Bottom	0.76	2.7	1.45	0.68	9
LT	**Surface**	0.53	2.74	1.41	0.65	9
	Bottom	0.53	2.74	1.44	0.63	9
Diurnal	**Surface**	0.48	1.22	0.88	0.24	10
	Bottom	0.72	1.55	1.19	0.42	10
June	**Surface**	0.16	0.58	0.33	0.15	9
	Bottom	0.21	2.54	0.84	0.86	9

(n* – number of values)

Table 9 : Range and Average of PO_4-P during different sampling periods:

Diurnal stations also showed similar changes in PO_4 as shown by transect stations. During monsoon, while surface values fluctuated within a narrow limit, the bottom values at some of the stations remained much higher.

Chlorophyll- *a*:

Chlorophyll *a*, which is a measure of phytoplankton biomass, remained sufficiently low during May. The chlorophyll *a* values ranged from 0.17 to 0.57 (avg. 0.37) mg/m^3, in surface waters during high tide, with similar values in the bottom waters. Not much difference was observed in the chlorophyll levels during low tide and diurnal stations. However, much higher values observed in June ranging from 0.63 to 1.93 (average 1.26) mg/m^3,may be due to less saline condition and higher nutrients availability in the estuary.

Sampling Details		Min	Max	Mean	St Dev	n
May HT	**Surface**	0.17	0.57	0.37	0.13	9
	Bottom	0.17	0.51	0.29	0.13	9
LT	**Surface**	0.23	0.34	0.30	0.05	9
	Bottom	0.17	0.51	0.33	0.10	9
Diurnal	**Surface**	0.63	1.93	1.26	0.47	10
	Bottom	0.4	1.25	0.83	0.23	10
June	**Surface**	0.63	1.93	1.26	0.47	9
	Bottom	0.4	1.25	0.83	0.23	9

(n* – number of values)

Table 10 : Range and Average of Chlorophyll during different sampling periods:

Zooplankton Biomass :

The biomass of zooplankton during high tide showed large fluctuation in values ranging from 0.99 to 10.66 (average 3.5) ml/100m^3. Similar values were reported during low tide sampling. At diurnal station, although the range in biomass occurrence was lower, the average values were almost similar to that of transect stations. The biomass values in June remained much higher ranging from 2.59 to 38.61 (average 11.86) ml/100m^3. According to Goswami *et al* (1979), the highest value of zooplankton biomass was obtained during the period of low saline regime .The species richness and eveness were inversely related to zooplankton biomass (Padmavati & Goswami, 1996).

Sampling Details	Min	Max	Mean	St Dev	n
May HT	0.99	10.66	3.50	2.81	9
LT	1.01	11.06	4.02	3.14	9
Diurnal	1.02	6.63	3.58	1.79	10
June	2.59	38.61	11.86	11.95	9

(n* – number of values)

Table 11 : Range and Average of Zooplankton Biomass during different sampling periods

Zooplankton Density :

The variation in Zooplankton density was also sufficiently large ranging from 5376 to 133755 (average 43368) no/100m^3 during flood tide at transects stations. Density remained much higher during ebb tide observation ranging from 54747 to 4225545 (average 1453982) no/100m^3.This shows that in the estuarine region the Zooplankton density remained higher than in the neritic costal zone. During low tide the density values at diurnal stations were much lower than the transect stations.

The June observations on the other hand showed that zooplankton density was comparable to the May values ranging from 16118 to 126887 (average 51919) no/ 100m^3.

Sampling Details	Min	Max	Mean	St Dev	n
May HT	5376	133755	59496	46368	9
LT	54747	4225545	967384	1453982	9
Diurnal	15276	154780	82062	40942	10
June	16118	126887	51919	35867	9

(n* – number of values)

Table 12 : Range and Average of Zooplankton Density during different sampling periods

Group distribution :

At the transect stations, during flood tide, the zooplankton population was represented by 20 groups **(Plate 15 to25)**; among these copepods were the most abundant constituting 89% of the population. This was followed by decapods 3.3%, lucifers, 2.5% gastropod larva and bivalves 1.57%. The highest number of copepods (118919 no/100m^3) was encountered at station 4 and the lowest 3207/100 m^3 at station 7. Distribution of fish eggs and larva showed a density range, from 6 to 135 /100 $m^3$of fish larvae and for eggs 16 to 1081 no/100 m^3. These together constituted to less than 0.5% of total zooplankton population.

Plate 15: ***Acartia sp.***

Plate 16 : ***Rhincalanus rostifrons***

Plate 17 :Copepod Nauplii

Plate 18 : Oncaea sp.

Plate 19 : Coryceus sp.

Plate 20 : Fish Egg

Plate 21 : Brachyuran Zoea

Plate 22 : Protozoea of Lucifer

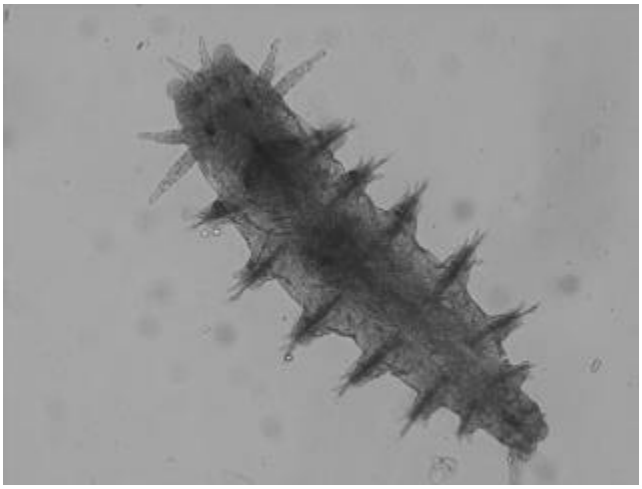

Plate 23 : Polychaete Larvae

Plate 24 : Fish Larvae

Plate 25 : Brachyuran Zoea of the crab *Portunus pelagicus*

During ebb tide observation, the number of groups representing zooplankton was reduced to 14. Copepoda was the dominant group constituting 94% of the total population. This was followed by decapods (2.1%), lucifer 1.5% and bivalve larvae 1.1%. In terms of quantity the number of copepods observed during ebb tide were much higher ranging from 51231 to 4057030 no/100 m^3 than the flood tide sampling period. Although percentage of fish eggs and larvae was much lower (0.1%); their numbers varied from 1 to 594/100 m^3 for fish larvae and from 91 to 3168 no/100 m^3 for fish eggs which lies much higher than the flood tide observations. Although the number of fish eggs and larva varied from one location to the other, they occurred at every station during flood and ebb tide observations as seen with copepods and decapods.

The diurnal observation at the construction site also showed that among the 21 zooplankton groups recorded, Copepoda was the most dominant group constituting about 94% of zooplankton population. The other groups were decapods 1.85%, bivalve larva 1.22%, lucifer 0.9% and chaetognatha 0.5 %. Population number showed that the number of copepods ranged from 12498 to 144534 no/100 m^3. These values are much higher than high tide observations. Fish eggs and larvae, which remained around 0.1%, fluctuated between 0 and 131no/100m^3 for fish larvae and from 3 to 301 no/100 m^3 for fish eggs. These values were much lower than other tidal stations in the Marmugao Bay. However, fish eggs and larvae were not detected at every observation as seen with transect stations. Fish larvae were not observed during night time sampling but appeared at early morning hours Physical disturbance due to movement of vessels near construction site may be responsible to keep the larval population away.

In the month of June, the zooplankton population was represented by 12 groups. Copepods remained to be the dominant group with 92% occurrence followed by decapods 4.4%, nauplius 1.9% and lucifer 0.9%, while others formed the minor groups. The total number of copepods at all the stations ranged from 14794 to 122789 no/100 m^3. These values were comparable to the high tide values observed in May 2004. The fish eggs and larvae which constituted around 0.3% of the population, showed their numbers varying, from 0 to 99 no/100 m^3 for larvae and from 0 to 425 no/100 m^3 for fish eggs. The values were much lower than the observations in May 2004. This indicates that month of May is more favorable for breeding of larvae and sudden change in salinity in June may inhabit some of the neritic fish eggs and larvae. Hence, the fish larvae could be absent at most of the stations as seen in June.

Diversity :

In order to understand the population distribution in more details the diversity indices were calculated for zooplankton groups at each station. The diversity of zooplankton was calculated using the Shannon and Weaver (1949) diversity index. These included species richness (D), evenness (J'), and Shannon diversity index (H'). The Shannon diversity index during high tide ranged from 0.84 to 1.32 (avg. 1.02) while J' ranged from 0.3 to 0.52 (avg. 0.39) and D from 0.9 to 1.7 (avg1.18) during low tide observations. In May, H' ranged from 0.19 to 0.42 (avg. 0.34), J' from 0.11 to 0.7 (avg. 0.15) and D from0.33 to 1(avg. 0.77). At the diurnal stations the diversity indices varied as; H' from 0.16 to 0.68 (avg. 0.34), J' from 0.06 to 0.28 (avg. 0.14) and D from 0.81 to 1.22. The monsoon observations showed that H' ranged from 0.83 to 1.05 (avg.0.91), J' 0.37 to 0.52 (avg. 0.43) and D 0.42 to 0.86 (avg. 0.65).

The mean value showed that group diversity and evenness were higher during flood tide observations in May, in spite of turbidity remaining high during this period. The group dominance on the other hand was almost similar to low tide and diurnal observations. This is probably because of high numbers of groups from marine origin entering the estuary during high tide. The lower diversity indices during low tide at transect stations could because of less number of groups representing the zooplankton from estuarine region. At the diurnal stations the disturbance caused by moving vessels etc. might influence the group diversity keeping the values low.

In June although the number of groups were only 12, the diversity remained high.

Sampling Details	Min	Max	Avg	SD	n*
May HT	0.85	1.32	14.62	9.30	8
LT	0.20	0.42	8.57	4.31	8
DIURNAL	0.16	0.68	0.34	0.17	10
JUNE	0.78	1.05	0.91	0.08	9

(n* – number of values)

Table 13 : Range and Average of Zooplankton Diversity during different sampling periods

DISCUSSION

Tropical estuaries are highly dynamic owing to the variation in the tidal forces, energy of the river at the confluence, which vary as per the season and interplay of these forces result in the complicated sedimentary environment. In addition to these the source and hydrodynamic condition of the transport media and mineral composition, influence the variation in texture of the sediment. The morphological feature such as tidal delta / bars, spit formation, lagoons, etc also play an important role in the estuarine sediment (Dyer,1979). The urbanization and anthropogenic activities also influence the sedimentation process and siltation is a common problem in the tropical estuaries.

Pelagic and benthic communities in nearshore marine environments are subjected to siltation process and turbidity, which in turn are considered as stress factors to these organisms (Rogers, 1990 and Anthony and Fabricius 2000). Researchers seeking to understand response of the inshore ecosystems to such stress and to minimize the potential impact of anthropogenic disturbances, are faced with two key questions:

What constitutes to a significant increase in turbidity? and

What is the turbidity threshold above which significant environmental change is expected?

These factors are critical to the environmetalist seeking to establish threshold or trigger levels of construction related activities (i. e. dredging or sediment discharge), above which operations need to be modified or stopped. Hence any turbidity increase above the natural regime should be under conditions that pose minimal environmental risk. The

present study undertaken to assess the ecological stress effects on zooplankton assemblages indicated that the standing stock of these organisms was sufficiently high.

The variations observed at each location during different tidal cycles and seasons could reflect the changes in environmental parameters. Vertical profiles of salinity and temperature during premonsoon (May) indicate that the estuary acts as an arm of the coastal waters with limited exchange of fresh water. Hence most of the environmental parameters showed very little variation with change in tides. Probably the coastal water mass moves up and down along the course of the estuary with a limited water outflow during the ebb tide that is enriched with nutrients and organic matter derived from Mangrove swarms and land activities.

Interestingly this pattern got disrupted at the onset of monsoon in June. A perfect gradient in vertical salinity regime with less saline waters was observed flowing over the typically dense saline marine waters near the estuarine mouth. This is the result of fresh water input from land run off during monsoon. Similar changes are reflected in temperature gradient too but these are less conspicuous than salinity.

Hegde *et al* (2004), while studying that sedimentation patterns in the Sharavati estuary in Karnataka, observed that the estuarine sediments are relatively fine grained during December to February (premonsoon), which are mainly derived from offshore source, brought by tidal currents. But during monsoon high energy condition enabled the river Sharavati to discharge its sediment load into the sea. Mohan (2000), studied the sediment transport in the Vellar Estuary and observed that the tidal activity had a significant effect on depositional processes in that estuary. Similar condition is

applicable in the Zuari estuary also, where turbidity, observed during the dry season in May is mainly derived from dredging activity as well as that from sea water input during flood tide, while that in June (monsoon), it is related to land drainage (Allen *et al*, 1980 and Hossain *et al*, 2004)

In order to understand the interrelation between the environmental and biological parameters such as zooplankton biomass, numerical counts and Shannon diversity index, the data was subjected to regression analysis. **Fig A** gives the regression (r) values of various physical and biological parameters at transact stations during high tide and low tide sampling (only bottom values are considered for environmental parameters in May). It can be seen that the turbidity shows significant positive relation with zooplankton diversity, nitrates and phosphates and negative relation with temperature. This suggests that the zooplankton diversity is not much affected by turbidity of water, while the later is responsible to enrich the water with nitrate and phosphate nutrients. The negative relation of turbidity with temperature suggests that estuarine waters contributed to turbidity to a lesser extent during May. This further confirms our results that the sediment in premonsoon enters the estuary from offshore source due to the tidal effect and low energy of the river and also as a result of ongoing dredging activity in the harbour region.

The group diversity of zooplankton showed inverse relation with temperature and NO_2. This suggests that low zooplankton diversity is associated with waters of estuarine origin having higher temperature than offshore waters. It has been reported that zooplankton diversity in estuarine waters is generally low (Vannuchi *et al*, 1970). There is usually a progressive gradient in zooplankton diversity from estuaries and lagoons to nearshore and coastal environments; oceanic regions maintain still higher diversity.

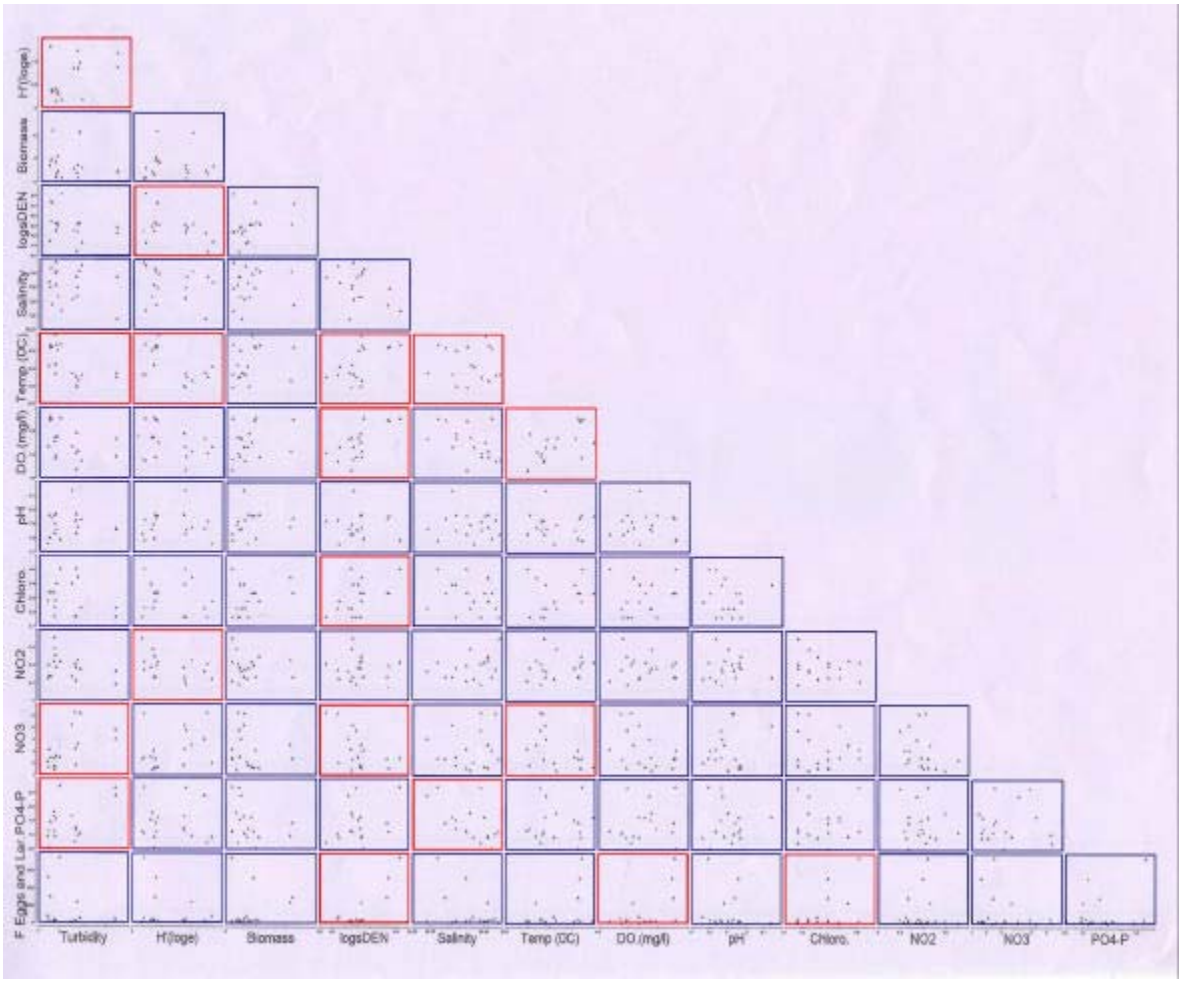

Fig. A - Regression (R) Values Of Various Physical And Biological Parameters At Transact Stations During High Tide And Low Tide Sampling in May, 04

= $p \leq 0.1$

Rigors of environment contribute to low diversity of the estuarine fauna. Among the several arguments advanced to explain low species diversity encountered in nature, the more cognate reasoning with respect to tropical estuaries pertain to the lack of stability (Ricklefs, 1973) and the same could be applicable to the present studies in Zuari estuary. According to Ramaiah (1997), diversity indices (Shannon-Weaver's H' and Margalef's D) were higher in the outer coastal waters than in creek zone indicating lethal or sub lethal effect of industrial and domestic wastes on the faunistic composition as well as water quality of the creek stations. But in Zuari estuary no such pollution was observed and variation in zooplankton and fish eggs and larvae could only occur due to the natural causes.

Although biomass did not show any distinct relation, the population density was positively related to temperature, DO, chlorophyll and fish eggs and larval density and negatively related to NO_3. This suggests that warm estuarine waters, which are well oxygenated with sufficient phytoplankton crop, offer a favorable environment for proliferation of zooplankton community as well as fish eggs and larvae. The contribution of zooplankton to nitrate levels in water is however limited, as seen from its negative relation. In the straits of Malacca, which has been classified as typical shallow sea with partially mixed water of estuarine origin, Razai *et al,* (2003) observed that higher zooplankton biomass was associated with higher amount of chlorophyll *a*, in the near coastal areas. Chandramohan and Sreenivas (1998), studied the zooplankton population in Gadesu Canal South east coast of India, have shown large planktonic crop mainly surviving on the rich phytoplankton and detritus from mangrove ecosystem, which is the main source of food for these organisms. These observations are in

agreement with the present studies where zooplankton population diversity has shown positive correlation with chlorophyll - *a*.

Fish eggs and larvae showed positive relationship with chlorophyll-*a* and DO, which are the basic requirements for better survival and growth of these organisms. In the Mumbai Harbour waters it was observed that the tidal flow had largely influenced the polluted bay waters where at least one third water gets renewed at every tidal cycle which helped to maintain normal dissolved oxygen level and reduced organic load for zooplankton and fish larvae to survive (Swami *et al*, 2000). Similar exchange of tidal waters in the Mormugao Harbour, which maintains nutrients, is responsible to keep phytoplankton and oxygen levels high for the proliferation of zooplankton and fish eggs and larvae. Positive relation of temperature with DO and negative relation with NO_3 suggest that estuarine waters are well saturated with oxygen and impoverished with nitrates, compared to coastal waters in premonsoon. Also input of nitrates from dredged sediments appears to be substantially low. The dredged sediments from Zuari mouth were also free from pollution load.

The statistical relations observed at transect stations are also reflected in the diurnal sampling results (**Fig. B).**

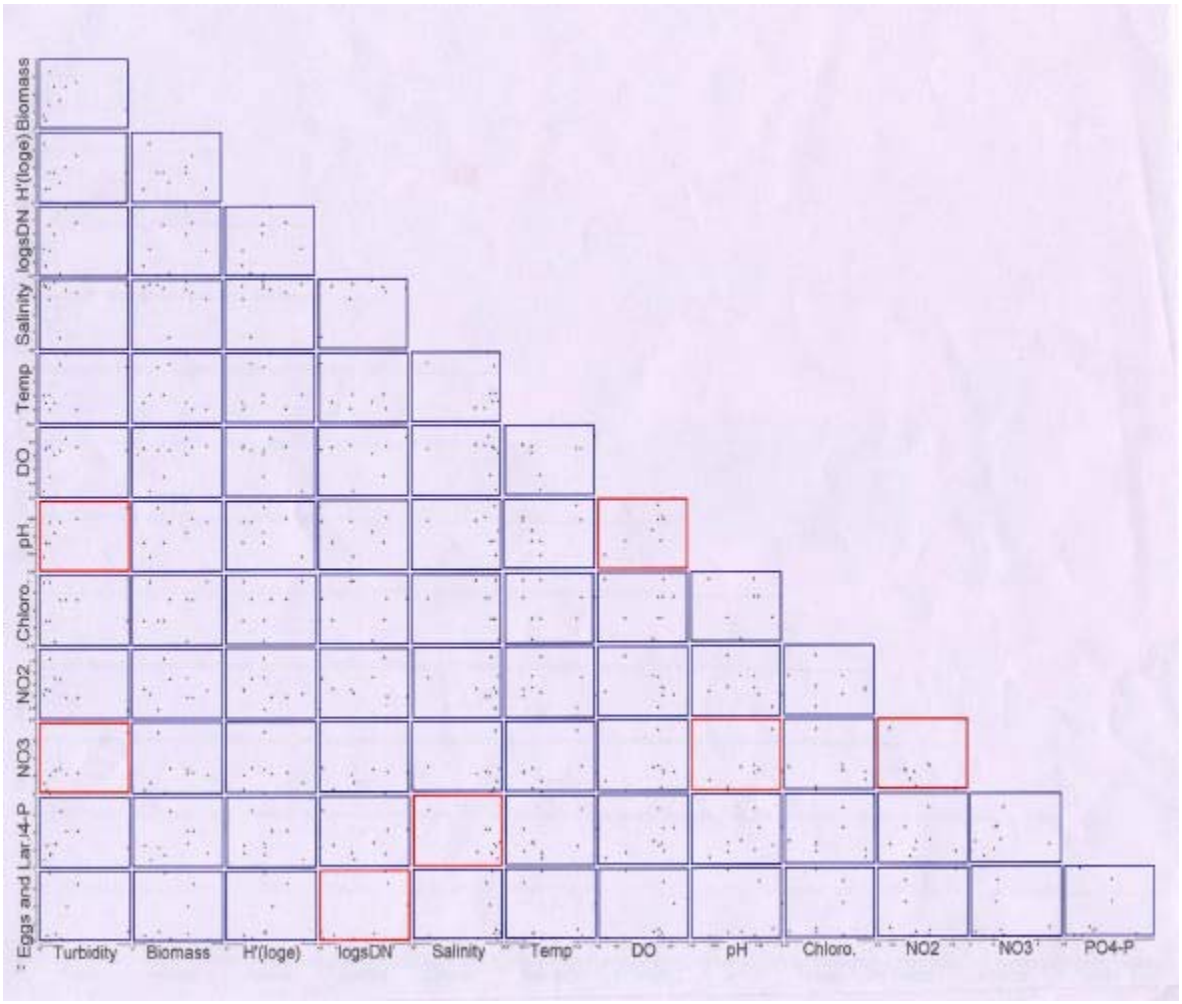

Fig. B: Regression (R) Values Of Various Physical And Biological Parameters At Diurnal Stations in May, 04

$= p \leq 0.1$ □

Somewhat changed pattern could be observed in monsoon (**Fig. C).** The higher turbidity in bottom waters during this period, which is mainly of marine origin, reduces Do and pH (negative relation) while contributing to nitrate (positive relation) in sufficient quantities to water column. The zooplankton biomass was directly related to their numerical abundance and DO. The salinity was negatively related to the density that indicates salinity of lower estuaries favored zooplankton survival. Similarly lower pH also helped the growth of fish eggs and larvae (negative relation) in the estuary. Paulinose *et al* (1998) have reported changes in biomass and numerical abundance of zooplankton depending upon tidal variability in Gulf of Kachchh waters. Zooplankton density, species composition and the relative abundance of major constituent showed well-marked seasonal variation. The annual cycle showed biomodal oscillations with a major peak during May/June and secondary peak in November .The distribution of zooplankton was significantly influenced by variation in salinity (Mishra and Panigrahy ,1999).

Ramaiah and Nair (1997) studied the copepod distribution in Mumbai Harbour area asserted that although salinity forms an important factor, the other environmental parameters such as temperature, pH, DO and nutrients also influenced the copepod diversity and abundance to a large extent.

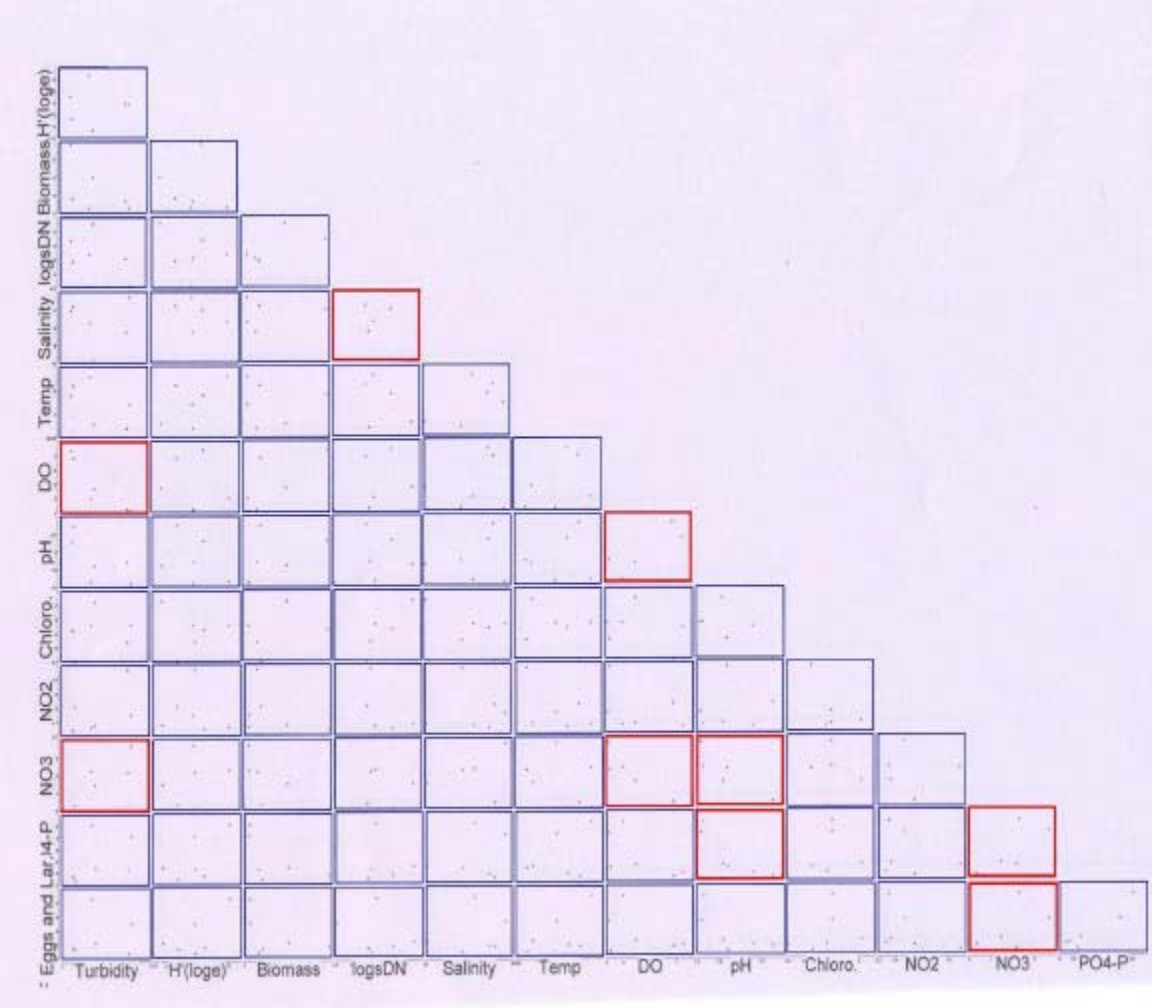

Fig. C : Regression (R) Values Of Various Physical And Biological Parameters In June

□ = $p \leq 0.1$

CONCLUSION

From the above observations it can be concluded that the turbidity arising from dredging activities had no direct effect on biological parameters such as group distribution and diversity of zooplankton as well as fish eggs and larvae. Although contribution to the phosphate content in water column from dredged sediments was to a substantial degree, the other nutrients such as nitrates remained low.

Turbidity observed in May (premonsoon) could be the combined effect of dredging as well as that from offshore sedimentation process associated with flood tidal current. However the dredged sediments appear to be free from pollution and there is little impact of the same on the biological communities in pelagic water column. Also estuarine environment, which contains high DO and adequate chlorophyll a, nutrients and mangrove derived organic matter, offers a favourable environment for the survival of zooplankton and fish eggs and larvae.

SUMMARY

Pelagic and benthic communities in the near shore marine environment are subject to siltation process arising from natural causes or human activities. These could act as stress factors to the living organisms. Dredging at ports a process of removing sediment debris from the navigational channel in order to permit larger ships to enter the berthing place. The present study has been carried out to understand "The impact of dredging on the water quality and group diversity of marine zooplankton during construction and reclamation activities of new berths at Mormugao Harbour". For this purpose physico-chemical and biological observations were carried out they are as follows:

Physical observations included vertical profile of temperature and salinity using CTD profiler.

Water quality parameters studied included pH, dissolved oxygen, nutrients such as nitrate, nitrite and phosphate.

The biological parameters included chlorophyll and zooplankton biomass and density.

The detailed field studies involved collection of surface and bottom water samples at nine stations along three different transects covering Mormugao bay, in order to trace the movement of sediments. Along these transects the sampling was carried out at two tidal cycles of high and low tides, for various chemical and biological parameters, in order to understand the influence of tides on turbidity and other related parameters. A diurnal sampling at single station was carried out to understand the changes occurring during 24 hrs. period.

The results of present study indicated that the temperature and salinity varied in a limited range during high, low tide and diurnal period of May 2004. But in monsoon (June 2004), the salinity remained much lower with larger difference between surface and bottom waters. Turbidity ranged from 7.2 to 68.8 NTU during the observation period. Higher turbidity could be assigned to dredging activities as well as to the tidal flow currents. Water quality parameters indicated that DO remains high ranging from 7.76 to 8.37 ml/l. Nutrients showed that while PO_4 remains high, the nitrates were low. Chlorophyll fluctuated in a narrow range of 0.11 to 0,63mg/m_3 in May 2004 with values remaining higher in June 2004 ranging from 0.4 to 1.93 mg/m_3. Zooplankton biomass in May 2004 ranged from 0.99 to11.06 ml/100m3 and from 2.59 to 38.61 ml/100m_3 in June 2004. Although biomass showed high values in June 2004, the population density remained much lower than May 2004. The group diversity of zooplankton showed higher values in May 2004 than the June 2004 samplings.

It appears therefore that although variation in parameters, station wise with changing tides is low, the seasonal differences are more distinct and especially associated with monsoon precipitation. The vertical profile of salinity and temperature during premonsoon (May 2004) indicates that the estuary act as an arm of the coastal waters with limited exchange of fresh water. Hence most of the environmental parameters showed very little variation with change in tides in May 2004. Interestingly this pattern gets disrupted at the onset of monsoon in June. And a perfect gradient in vertical salinity regime with less saline waters flowing over the typically dense saline marine waters is seen near the estuarine mouth. This is the result of fresh water input from land run off due to monsoon precipitation. Similar changes are reflected in temperature gradient also but these are less conspicuous than salinity. These changes result in large variation in

chemical and biological properties of these waters. Also any activity such as dredging or pollution due to harbour operation could have bearing on living organisms in the estuaries.

In order to understand the relation of water quality with biological parameters, the data was subjected to regression analysis. The results showed positive relation of turbidity with zooplankton diversity and that of population density to temperature, DO, Chlorophyll and fish eggs and larvae. These observations suggest that the turbidity arising from dredging activity has no direct effect on biological parameters such as group distribution and diversity of zooplankton as well as fish eggs and larvae. Although contribution to the phosphate content in water column from dredged sediments was to a substantial degree, the other nutrients such as nitrates remained low. It could be concluded therefore that the turbidity in May 2004 (premonsoon) could be due to the combined effects of dredging as well as that from offshore sedimentation processes associated with flood tides and currents. However the dredged sediments appear to be free from pollution and there is little impact of the same on the biological communities in pelagic water column. Also estuarine waters, which contain high DO and adequate chlorophyll a, nutrients and mangrove derived organic matter, offer a favourable environment for the survival of zooplankton and fish eggs and larvae.

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APPENDIX

Table-1.1 Composition of Zooplankton Density (no/100m3) in May 2004 during HighTide at different station of M.P.T.

Stations(#)	4	6	7	9	11	12	14	16	Total	Mean
GROUPS										
Copepoda	118919	47234	3207	77414	57710	31231	10462	115780	461957.2	57744.6
Decapoda	2731	1238	96	6178	1011	934	2929	2053	17169.9	2146.2
Nauplius	284	0	48	0	249	80	0	80	740.7	92.6
Zoea	626	151	32	212	156	67	139	139	1521.4	190.2
Lucifer	2048	936	1568	0	124	1815	2901	3587	12980.9	1622.6
Larvacea	57	24	0	0	47	120	84	40	371.0	46.4
Gastropoda larvae	3073	151	48	459	187	5726	28	139	9809.5	1226.2
Barnical larva	114	214	0	159	0	53	84	20	643.9	80.5
Cladocera	0	16	0	0	16	0	0	0	31.4	3.9
Cyprid	0	8	0	71	0	0	0	0	78.5	9.8
Polychaete	114	56	16	177	31	53	0	40	486.0	60.8
Siphonophore	114	0	0	0	78	40	112	139	482.7	60.3
Amphipoda	0	0	0	18	0	0	0	0	17.7	2.2
Cheatognath	683	127	285	353	0	547	251	498	2744.4	343.0
Stomatopoda	171	16	0	0	0	0	0	20	206.5	25.8
Cerripedia	57	0	0	0	0	13	0	0	70.2	8.8
Bivalve	3414	95	0	0	2178	2042	279	159	8167.3	1020.9
Echnoderm	0	0	0	0	0	0	0	20	19.9	2.5
Fish larvae	135	11	7	78	25	8	17	6	288.6	36.1
Fish eggs	1081	119	63	177	16	107	391	159	2112.3	264.0
Total	132404	50265	5298	85039	61785	42723	17269	122715	517499	64687

Table-1.1.1 Percentage of Zooplankton groups in May 2004 during High Tide at different station of M.P.T.

Stations(#)	4	6	7	9	11	12	14	16
GROUPS								
Copepoda	88.91	93.71	59.65	90.68	93.30	72.89	59.12	94.22
Decapoda	2.04	2.46	1.79	7.24	1.63	2.18	16.55	1.67
Nauplius	0.21	0.00	0.88	0.00	0.40	0.19	0.00	0.06
Zoea	0.47	0.30	0.59	0.25	0.25	0.16	0.79	0.11
Lucifer	1.53	1.86	29.17	0.00	0.20	4.24	16.40	2.92
Larvacea	0.04	0.05	0.00	0.00	0.08	0.28	0.47	0.03
Gastropoda larvae	2.30	0.30	0.88	0.54	0.30	13.36	0.16	0.11
Barnical larva	0.09	0.43	0.00	0.19	0.00	0.12	0.47	0.02
Cladocera	0.00	0.03	0.00	0.00	0.03	0.00	0.00	0.00
Cyprid	0.00	0.02	0.00	0.08	0.00	0.00	0.00	0.00
Polychaete	0.09	0.11	0.29	0.21	0.05	0.12	0.00	0.03
Siphonophore	0.09	0.00	0.00	0.00	0.13	0.09	0.63	0.11
Amphipoda	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00
Cheatognath	0.51	0.25	5.30	0.41	0.00	1.28	1.42	0.41
Stomatopoda	0.13	0.03	0.00	0.00	0.00	0.00	0.00	0.02
Cerripedia	0.04	0.00	0.00	0.00	0.00	0.03	0.00	0.00
Bivalve	2.55	0.19	0.00	0.00	3.52	4.77	1.58	0.13
Echnoderm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Fish larvae	0.10	0.02	0.13	0.09	0.04	0.02	0.10	0.01
Fish eggs	0.81	0.24	1.18	0.21	0.03	0.25	2.21	0.13

Table-1.2 Composition of Zooplankton Density (no/100m3) in May 2004 during Low Tide at different station of M.P.T.

Stations(#)	4	6	7	9	11	12	14	16	Total	Mean
GROUPS										
Copepoda	121602	145596	51231	113316	95810	4057030	1449782	1258734	7293101	911638
Decapoda	3908	1742	1460	2977	1989	88713	40175	20832	161795	20224
Nauplius	35	62	41	113	36	0	1747	145	2179	272
Zoea	226	233	207	249	438	0	0	2459	3812	476
Lucifer	3004	2084	1102	2773	3248	60198	0	46148	118558	14820
Chaetognath	87	156	110	45	201	6337	7686	579	15199	1900
Larvacea	87	0	14	23	18	0	4891	868	5900	738
Gastropoda larvae	365	856	96	985	18	0	15721	9693	27733	3467
Bivalve larvae	990	5584	220	3181	73	0	50655	20398	81101	10138
Cladocera	382	0	55	0	18	0	1397	0	1853	232
cerripedial	0	0	0	0	0	0	0	145	145	18
Polychaete	191	93	0	34	109	9505	4192	1591	15716	1965
Siphonophore	122	0	41	11	0	0	0	3183	3357	420
Fish larva	7	1	4	11	19	594	153	36	826	103
Fish eggs	156	202	165	125	91	3168	2445	1447	7800	975
Total	131160	156610	54747	123844	102070	4225545	1578843	1366257	7739075	967384

Table-1.2.1 Percentage of Zooplankton groups in May 2004 during Low Tide at different station of M.P.T.

Stations(#)	4	6	7	9	11	12	14	16
GROUPS								
Copepoda	92.71	92.97	93.58	91.50	93.87	96.01	91.83	92.13
Decapoda	2.98	1.11	2.67	2.40	1.95	2.10	2.54	1.52
Nauplius	0.03	0.04	0.08	0.09	0.04	0.00	0.11	0.01
Zoea	0.17	0.15	0.38	0.20	0.43	0.00	0.00	0.18
Lucifer	2.29	1.33	2.01	2.24	3.18	1.42	0.00	3.38
Chaetognath	0.07	0.10	0.20	0.04	0.20	0.15	0.49	0.04
Larvacea	0.07	0.00	0.03	0.02	0.02	0.00	0.31	0.06
Gastropoda larvae	0.28	0.55	0.18	0.80	0.02	0.00	1.00	0.71
Bivalve larvae	0.75	3.57	0.40	2.57	0.07	0.00	3.21	1.49
Cladocera	0.29	0.00	0.10	0.00	0.02	0.00	0.09	0.00
Polychaete	0.15	0.06	0.00	0.03	0.11	0.22	0.27	0.12
cerripedial	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Siphonophore	0.09	0.00	0.08	0.01	0.00	0.00	0.00	0.23
Fish larva	0.00	0.00	0.01	0.01	0.02	0.01	0.01	0.00
Fish eggs	0.12	0.13	0.30	0.10	0.09	0.07	0.15	0.11

Table-1.3 Composition of Zooplankton Density(no/100m3) in May 2004 during Diurnal at different station of M.P.T.

Time	11:00	13:00	15:00	17:00	21:00	23:00	19:00	3:00	7:00	11:00	Total	Mean
GROUPS												
Copepoda	111908	72916	72656	58041	116465	12498	144534	48788	89484	46359	773649	140663
Decapoda	1966	2244	881	921	610	1950	2532	678	2055	1321	15157	2756
Nauplius	33	127	534	82	0	0	623	0	214	37	1650	300
Zoea	33	362	80	66	27	0	390	75	471	187	1690	307
Lucifer	475	959	347	181	796	100	312	603	1541	1869	7183	1306
Euphausiacea	0	0	0	0	0	0	0	0	0	0	0	0
Mysidacea	0	0	0	0	0	50	0	0	0	0	50	9
Chaetognath	541	271	160	49	1380	250	0	844	514	100	4108	747
Larvacea	33	18	0	0	27	0	117	0	43	12	250	45
Gastropoda larvae	360	181	133	0	27	50	467	121	2312	87	3739	680
Bivalve larvae	0	688	561	99	0	275	5454	166	2569	199	10010	1820
Cladocera	0	0	0	0	0	0	0	0	0	0	0	0
Polychaete	98	18	27	99	80	25	78	0	43	0	467	85
Siphonophore	0	36	107	0	133	50	195	0	86	37	643	117
Cladocera	0	36	0	0	0	25	39	0	0	50	150	27
Megalopa	0	0	0	0	27	0	0	0	0	0	27	5
Barnical larva	0	0	0	0	27	0	0	0	86	0	112	20
Stomatopoda	0	0	0	0	27	0	0	211	128	0	366	67
Cephanophore	16	0	0	0	0	0	0	0	0	0	16	3
Ostrocord	0	0	0	0	0	0	0	15	0	0	15	3
Fish larvae	131	18	2	16	0	0	0	90	128	50	436	79
Fish eggs	147	36	8	16	3	3	39	301	198	150	903	164
Total	**115741**	**77910**	**75495**	**59570**	**119625**	**15276**	**154780**	**51892**	**99872**	**50459**	820620	149204

Table-1.3.1 Percentage of Zooplankton groups in May 2004 during Diurnal at different station of M.P.T.

Time	11:00	13:00	15:00	17:00	21:00	23:00	19:00	3:00	7:00	11:00
GROUPS										
Copepoda	96.69	93.59	96.24	97.43	97.36	81.81	93.38	94.02	89.60	91.87
Decapoda	1.70	2.88	1.17	1.55	0.51	12.76	1.64	1.31	2.06	2.62
Nauplius	0.03	0.16	0.71	0.14	0.00	0.00	0.40	0.00	0.21	0.07
Zoea	0.03	0.46	0.11	0.11	0.02	0.00	0.25	0.15	0.47	0.37
Lucifer	0.41	1.23	0.46	0.30	0.67	0.65	0.20	1.16	1.54	3.70
Euphausiacea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mysidacea	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00
Chaetognath	0.47	0.35	0.21	0.08	1.15	1.64	0.00	1.63	0.51	0.20
Larvacea	0.03	0.02	0.00	0.00	0.02	0.00	0.08	0.00	0.04	0.02
Gastropoda larvae	0.31	0.23	0.18	0.00	0.02	0.33	0.30	0.23	2.31	0.17
Bivalve larvae	0.00	0.88	0.74	0.17	0.00	1.80	3.52	0.32	2.57	0.40
Polychaete	0.08	0.02	0.04	0.17	0.07	0.16	0.05	0.00	0.04	0.00
Siphonophore	0.00	0.05	0.14	0.00	0.11	0.33	0.13	0.00	0.09	0.07
Cladocera	0.00	0.05	0.00	0.00	0.00	0.16	0.03	0.00	0.00	0.10
Megalopa	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
Barnical larva	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.09	0.00
Stomatopoda	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.41	0.13	0.00
Siphonophore	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ostrocord	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00
Fish larvae	0.11	0.02	0.00	0.03	0.00	0.00	0.00	0.17	0.13	0.10
Fish eggs	0.13	0.05	0.01	0.03	0.00	0.02	0.03	0.58	0.20	0.30

Table-1.4 Composition of Zooplankton Biomass(ml/100m3) in June 2004 at different station of M.P.T.

Stations(#)	1	4	6	7	9	11	12	14	16	Total
GROUPS										
Copepoda	15073	35807	74955	64633	37477	122789	23701	14794	39557	428787
Decapoda	1271	1147	2535	6178	1758	2296	1236	476	3686	20581
Nauplius	1341	0	348	2780	773	254	721	435	2127	8778
Lucifer	247	295	1193	154	949	694	227	145	213	4117
Polychaeta	53	229	298	0	35	0	82	21	142	860
Medusa	18	33	0	0	0	0	0	0	0	50
Barnical larva	282	295	398	0	70	747	144	0	142	2079
Amphipoda	0	0	50	0	0	0	0	0	0	50
Brachiuran Zoea	0	0	99	0	0	0	0	0	0	99
Larvacae	53	0	0	0	0	0	41	0	567	661
fish larvae	0	66	99	0	0	0	21	0	0	186
Fish eggs	71	0	0	77	35	107	62	248	425	1025
Total	18339	37871	79975	73745	41064	126780	26172	15870	46433	466249

Table-1.4.1 Percentage of Zooplankton groups in June 2004 at different station of M.P.T.

Stations(#)	1	4	6	7	9	11	12	14	16
GROUPS									
Copepoda	81.88	94.55	93.72	87.55	91.19	96.77	90.35	91.78	84.42
Decapoda	6.90	3.03	3.17	8.37	4.28	1.81	4.71	2.95	7.87
Nauplius	7.29	0.00	0.44	3.77	1.88	0.20	2.75	2.70	4.54
Lucifer	1.34	0.78	1.49	0.21	2.31	0.55	0.86	0.90	0.45
Polychaeta	0.29	0.61	0.37	0.00	0.09	0.00	0.31	0.13	0.30
Medusa	0.10	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Barnical larva	1.53	0.78	0.50	0.00	0.17	0.59	0.55	0.00	0.30
Amphipoda	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00
Brachiuran Zoea	0.00	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.00
Larvacae	0.29	0.00	0.00	0.00	0.00	0.00	0.16	0.00	1.21
fish larvae	0.00	0.17	0.12	0.00	0.00	0.00	0.08	0.00	0.00
Fish eggs	0.38	0.00	0.00	0.10	0.09	0.08	0.24	1.54	0.91

Table : 1.5 Biomass(ml/100m3) values in different months of 2004

	May High Tide	May Low Tide	MAY DINUAL 2004		JUNE	
Station/Time	Biomass	Biomass	Time	Biomass	Station	Biomass
4	10.66	5.42	11:00	3.07	1	4.412
6	0.99	4.86	13:00	2.26	4	8.19
7	1.98	1.72	15:00	3.33	6	18.639
9	2.20	4.24	17:00	1.02	7	38.61
11	2.91	2.28	21:00	6.63	9	6.591
12	2.50	1.01	23:00	1.56	11	20.02
14	3.48	4.58	19:00	4.86	12	5.148
16	3.73	11.06	3:00	2.82	14	2.586
			7:00	5.35	16	2.586
			11:00	4.86		

Table-2.1 Hydrographic characteristics of Sea Water in M.P.T. during High Tide in May 2004 at different sampling stations

Station no.	Depth	Temperature	Salinity	DO.(mg/l)	pH	Silicates	PO4-P	NO3-N	NO2	chlorophyll	Turbidity
		(0C)				µmol/l	µmol/l	µmol/l	µmol/l	mg/m3	
1	Surface	30.2	35.2	4.96	7.81	2.78	0.58	6.2	0.31	0.57	29.6
	Bottom	30.3	35.44	4.87	7.97	4.8	0.9	6.25	0.4	0.23	37
4	Surface	30.8	36.2	5.04	8.01	4.39	1.22	6.05	0.25	0.17	55
	Bottom	30.9	35.35	5.08	7.88	8.28	0.99	3.64	0.46	0.45	34.4
6	Surface	30.5	34.74	5.24	7.99	9.29	1.73	5.81	0.29	0.4	23.9
	Bottom	31	35.13	4.68	7.83	2.53	1.18	3.25	0.23	0.51	32.8
7	Surface	31.2	35.24	4.88	7.92	9.85	0.53	2.18	0.29	0.51	32.4
	Bottom	30.7	35.3	5.04	7.92	9.19	0.76	6.32	0.42	0.17	32.1
9	Surface	31.5	35.38	5.07	7.85	11.71	1.91	4.95	0.21	0.4	44.4
	Bottom	31	35.24	4.97	7.86	3.48	2.7	4.86	0.19	0.17	67.9
11	Surface	31.7	35.2	5.03	7.87	10.1	1.13	4	0.29	0.34	27
	Bottom	31.5	35.32	5.17	8.14	9.54	1.68	5.28	0.27	0.4	29
12	Surface	31.2	35.11	5.31	7.84	8.23	2.01	4.78	0.34	0.23	68.8
	Bottom	30	34.89	5.34	7.87	3.13	2.42	4.09	0.34	0.23	68.1
14	Surface	31.8	35.12	5.13	7.97	11.26	1.27	1.73	0.46	0.4	46.4
	Bottom	31.1	35.29	5.17	7.76	9.24	0.95	2.1	0.25	0.28	7.9
16	Surface	31.4	34.78	5.31	7.92	10.4	0.99	1.09	1.07	0.28	30.2
	Bottom	31.1	34.58	5.46	7.97	8.18	1.27	1.84	0.38	0.17	32.7
	Min	**30**	**34.74**	**4.68**	**7.76**	**2.53**	**0.53**	**1.09**	**0.19**	**0.17**	**7.9**
	Max	**31.8**	**36.2**	**5.34**	**8.14**	**11.71**	**2.7**	**6.32**	**1.07**	**0.57**	**68.8**
	Mean	**30.99**	**35.23**	**5.08**	**7.91**	**7.54**	**1.35**	**4.13**	**0.36**	**0.34**	**39.23**
	St Dev	**0.52**	**0.32**	**0.18**	**0.09**	**3.22**	**0.63**	**1.75**	**0.20**	**0.13**	**17.08**

Table-2.2 Hydrographic characteristics of Sea Watwr in M.P.T. during Low Tide in May 2004 at different sa mpling stations

Station no	Depth	Temperature	Salinity	DO.(mg/l)	pH	Silicates	PO4-P	NO3-N	NO2	chlorophyll	Turbidity
		(0C)				µmol/l	µmol/l	µmol/l	µmol/l	mg/m3	
4	Surface	31.8	35.23	5.03	7.85	9.29	0.95	0.51	0.76	0.28	17.6
	Bottom	31.4	35.31	4.96	7.97	10.25	0.99	1.65	0.51	0.28	14.7
6	Surface	31.8	35.16	5.58	7.93	11.76	0.53	1.87	0.51	0.34	12.4
	Bottom	31.7	35.18	5.78	7.8	10.91	1.27	3.16	0.27	0.34	9.23
7	Surface	31.6	35.02	5.47	7.95	4.75	1.82	1.18	0.48	0.23	13.4
	Bottom	31	35.22	5.38	7.9	11.01	1.22	1.47	0.59	0.23	14
9	Surface	31.7	35.22	5.31	7.94	4.29	1.64	2.23	0.38	0.28	16.9
	Bottom	31.5	35.33	5.27	7.96	8.68	0.72	1.7	0.44	0.34	13.6
11	Surface	32	35.03	5.38	7.93	4.24	1.55	3.9	0.36	0.34	29.7
	Bottom	31.7	32.68	5.37	7.86	11.71	2.1	2.59	0.38	0.4	15.6
12	Surface	31.9	35.32	5.54	7.81	4.95	2.74	1.67	0.53	0.34	24.2
	Bottom	31.5	35.08	5.77	7.79	4.65	1.27	2.5	0.44	0.51	18.5
14	Surface	31.8	35.1	5.71	7.82	11.16	1.13	3.3	0.4	0.34	15.3
	Bottom	31.5	34.92	5.73	7.96	12.98	2.71	1.62	0.4	0.34	8.9
16	Surface	31.8	35.12	6.06	7.79	11.56	1.45	1.84	0.29	0.28	7.55
	Bottom	31.4	35.05	5.75	7.94	9.39	1.55	2.43	0.27	0.34	10.5
	Min	**31**	**32.68**	**4.96**	**7.79**	**4.24**	**0.53**	**0.51**	**0.27**	**0.17**	**7.55**
	Max	**32**	**35.33**	**6.06**	**7.97**	**12.98**	**2.74**	**3.9**	**0.76**	**0.51**	**29.7**
	Mean	**31.63**	**35.00**	**5.51**	**7.89**	**8.85**	**1.48**	**2.10**	**0.44**	**0.33**	**15.13**
	St Dev	**0.24**	**0.63**	**0.29**	**0.07**	**3.16**	**0.63**	**0.86**	**0.13**	**0.07**	**5.67**

Table-2.3 Hydrographic characteristics of Sea Water in M.P.T. during Diurnal in May 2004 at different sampling stations

TIME	Depth	Temperature	Salinity	DO.(mg/l)	pH	Silicates	PO4-P	NO3-N	NO2	chlorophyll	Turbidity
		(0C)				µmol/l	µmol/l	µmol/l	µmol/l	mg/m3	
11.00 AM	Surface	31	35.37	4.93	7.81	2.78	0.58	6.2	0.31	0.57	29.6
	Bottom	31	35.13		7.97	4.8	0.9	6.25	0.4	0.23	37
1.00 PM	Surface	31.1	35.03	4.96	7.99	3.23	0.81	1.65	0.46	0.57	14.2
	Bottom	31	35.39	4.87	7.93	3.53	1.06	8.96	0.36	0.17	59.2
3.00 PM	Surface	31.6	35.32	4.94	7.91	4.19	0.99	3.97	0.76	0.34	12.4
	Bottom	31.05	29.39	4.87	7.89	14.34	2.1	4.87	0.88	0.23	21.9
5.00 PM	Surface	30.8	35.45	5.01	7.79	5.2	0.85	5.73	0.46	0.23	13.5
	Bottom	30.5	35.24	4.9	7.83	7.47	1.13	2.39	0.71	0.17	13.9
7.00 PM	Surface	30.8	35.12	5.06	7.85	5.2	1.18	5.05	0.34	0.63	15
	Bottom	30.4	33.71	4.93	7.89	4.29	0.9	4.04	0.69	0.28	16
9.00 PM	Surface	30.5	35.42	4.63	7.77	4.7	0.9	3.82	0.59	0.4	14.1
	Bottom	30.6	35.46	4.28	7.79	8.53	0.72	3.16	0.63	0.28	12.8
11.00 PM	Surface	30.4	35.4	4.86	7.89	2.73	0.76	4.78	0.53	0.28	14.4
	Bottom	30.5	35.72	4.81	7.86	11.97	1.18	4.65	0.9	0.11	18.9
3.00 AM	Surface	30.5	35.49	5.07	7.81	5.66	0.48	4.78	0.04	0.28	16.3
	Bottom	30.6	35.04	4.5	7.83	2.88	0.85	2	1.24	0.17	15.8
7.00 AM	Surface	30.5	35.5	5.07	7.69	5.55	1.04	3.42	0.82	0.28	13
	Bottom	30.4	34.53	4.92	7.9	5.56	1.55	4.36	0.57	0.23	31.3
11.00 AM	Surface	31.8	34.97	5.07	7.93	13.94	1.22	5.53	0.97	0.17	25
	Bottom	31.2	34.88	5.04	7.95	14.04	1.55	4.2	0.57	0.23	25
	Min	**30.4**	**29.39**	**4.28**	**7.69**	**2.73**	**0.48**	**1.65**	**0.04**	**0.11**	**12.4**
	Max	**31.8**	**35.72**	**5.07**	**7.99**	**14.34**	**2.1**	**8.96**	**1.24**	**0.63**	**59.2**
	Mean	**30.8125**	**34.878**	**4.88**	**7.864**	**6.5295**	**1.0375**	**4.4905**	**0.6115**	**0.2925**	**20.965**
	St Dev	**0.402582126**	**1.363365032**	**0.2071768**	**0.0750719**	**3.9170847**	**0.3710706**	**1.6525243**	**0.2730197**	**0.144254**	**11.452156**

Table-2.4 Hydrographic characteristics of Sea Water in M.P.T. during June 2004 at different sampling stations

Station no	Depth	Temperature	Salinity	DO.(mg/l)	pH	Silicates	PO4-P	NO2	NO3-N	chlorophyll	Turbidity
		^{0}C				µmol/l	µmol/l	µmol/l	µmol/l	mg/m3	
1	Surface	29.3	21.46	7.36		24.67	0.44	0.43	0.14	0.97	11.4
	Bottom	29.05	33.16	4.7		17.79	0.54	0.64	1.62	0.68	31.9
4	Surface	30	21.33	8.22	8.31	23.79	0.58	0.19	0.11	1.02	7.38
	Bottom	29.5	23.6	6.85	8.15	15.82	0.21	0.62	0.34	0.4	11.9
6	Surface	29.8	21.93	7.94	8.05	23.01	0.26	0.23	0	0.91	8.28
	Bottom	29.5	22.14	8.11		25.34	0.21	0.17	0	0.85	17.7
7	Surface	29.6	21.18	7.57	7.97	21.67	0.3	0.5	0	0.68	13.4
	Bottom	29.1	20.14	7.4	8.06	28.85	0.35	0.29	0	0.85	10.3
9	Surface	29.5	21.19	7.73		25.03	0.49	0.39	0.0026	1.48	10.7
	Bottom	29	31.18	3.24	7.94	17.38	0.63	1.14	2.17	0.68	60.2
11	Surface	29.3	20.87	7.87	8.37	17.79	0.21	0.31	0	1.82	11.7
	Bottom	29.05	27.35	4.7	7.92	23.48	0.72	0.35	1.47	1.25	30.5
12	Surface	29.9	20.78	7.81	8.06	20.43	0.16	0.45	0	1.93	11.7
	Bottom	29	21.2	8.1	7.96	16.81	0.26	0.47	0	0.97	12.8
14	Surface	29.1	21.93	7.82	7.9	18.05	0.16	0.21	0	1.65	12.3
	Bottom	29	32.91	3.14	7.82	28.65	2.08	0.5	3.68	0.91	63.5
16	Surface	29	18.9	7.13	8.03	22.03	0.4	0.68	0.48	0.85	12.7
	Bottom	29	32.37	3.98	7.83	29.58	2.54	0.33	2.28	0.91	27.3
Min		29	18.9	3.14	7.82	15.82	0.16	0.17	0	0.4	7.38
Max		30	33.16	8.22	8.37	29.58	2.54	1.14	3.68	1.93	63.5
Mean		29.32	24.09	6.65	8.03	22.23	0.59	0.44	0.68	1.05	20.31
St Dev		0.34	4.89	1.79	0.16	4.35	0.65	0.23	1.09	0.42	16.77

Table-2.5 Suspended Sediments g/l at different stations during High Tide (HT) and (Low tide)LT in May and June 04

Stations(#)	Depth	Suspended Sediments May HT	Suspended Sediments May LT	June
1	Surface	0.035	0.034	NA
	Bottom	0.038	0.032	0.0491
4	Surface	0.046	0.0491	0.0281
	Bottom	0.047	0.0531	0.0331
6	Surface	0.050	0.0691	0.0281
	Bottom	0.220	0.0951	NA
9	Surface	0.146	0.0521	0.0351
	Bottom	0.070	0.0531	0.2141
11	Surface	0.058	0.0601	0.0351
	Bottom	0.073	0.0681	0.0541
14	Surface	0.048	0.0581	0.0391
	Bottom	0.053	0.0491	0.1701
16	Surface	0.054	0.0521	0.0401
	Bottom	0.062	0.0341	0.0601
	Min	**0.035**	**0.032**	**0.028**
	Max	**0.220**	**0.095**	**0.214**
	Mean	**0.072**	**0.054**	**0.066**
	St dev.	**0.051**	**0.016**	**0.061**

Suspended sediments (g/l) for diurnal sampling in May 04

Time	Depth	SS
11:00	Surface	0.035
	Bottom	0.038
15:00	Surface	0.036
	Bottom	0.042
17:00	Surface	0.034
	Bottom	0.032
23:00	Surface	0.035
	Bottom	0.037
3:00	Surface	0.045
	Bottom	0.044
7:00	Surface	0.040
	Bottom	0.041
11:00	Surface	0.045
	Bottom	0.048
	Min	0.032
	Max	0.048
	Mean	0.040
	St Dev	**0.005**

Table-3.1 Range and Average of different parameters during May High Tide.

Parameters	Min	Max	Average	SD	n
Temp.	30	31.8	30.99	0.52	9
Salinity	34.74	36.2	35.23	0.32	9
Turbidity	7.9	68.8	38.87	16.64	9
Suspended sediments	0.035	0.220	0.07	0.05	7
DO	4.68	5.34	5.08	0.18	9
pH	7.76	8.14	7.91	0.09	9
Silicates	2.53	11.71	7.54	3.22	9
PO_4-P	0.53	2.7	1.35	0.63	9
NO2	0.19	1.07	0.36	0.20	9
NO3	1.09	6.32	4.13	1.75	9
Chlorophyll	0.17	0.57	0.33	0.13	9
Zoopl. biomass	0.99	10.66	2.81	3.50	9
Zoopl. density	5376	133755	46368	59496	9

Table-3.1.1 Range and Average of different parameters during May High Tide at Surface.

Parameters	Min	Max	Average	SD	n
Temp.	30.16	30.55	0.14	30.33	9
Salinity	34.02	35.35	0.47	35.02	9
Turbidity	23.9	68.8	15.02	39.74	9
Suspended sediments	0.0351	0.146	0.06	0.04	7
DO	4.88	5.31	0.15	5.11	9
pH	7.84	8.01	0.06	7.93	9
Silicates	3.23	11.71	2.98	8.72	9
PO_4-P	0.53	2.01	0.50	1.29	9
NO2	0.21	1.07	0.26	0.41	9
NO3	1.09	6.2	4.09	1.96	9
Chlorophyll	0.17	0.57	0.13	0.37	9
Zoopl. biomass	0.99	10.66	2.81	3.50	9
Zoopl. density	5375.7054	133755.33	46367.57	59496.04	9

Table-3.1.2 Range and Average of different parameters during May High Tide at Bottom.

Parameters	Min	Max	Average	SD	n
Temp.	30.19	30.43	0.07	30.31	9
Salinity	34.24	35.43	0.06	35.36	9
Turbidity	7.9	68.1	19.01	37.99	9
Suspended sediments	0.0381	0.07	0.08	0.06	7
DO	4.68	5.46	0.24	5.09	9
PHC	6.57	108	87.07	31.05	9
pH	7.76	8.14	0.11	7.91	9
Silicates	2.53	9.54	3.06	6.34	9
PO_4-P	0.76	2.7	0.68	1.45	9
NO2	0.19	0.46	0.09	0.32	9
NO3	1.84	6.32	4.18	1.64	9
Chlorophyll	0.17	0.51	0.13	0.29	9
Zoopl. biomass	0.99	10.66	2.81	3.50	9
Zoopl. density	5375.7054	133755.33	46367.57	59496.04	9

Table-3.2 Range and Average of different parameters during May Low Tide.

Parameters	Min	Max	Average	SD	n
Temp.	31	32	31.63	0.24	8
Salinity	32.68	35.33	35.00	0.63	8
Turbidity	7.55	29.7	14.97	5.35	8
Suspended sediments	0.0341	0.0951	0.06	0.01	6
DO	4.96	6.06	5.51	0.29	8
pH	7.79	7.97	7.89	0.07	8
Silicates	4.24	12.98	8.85	3.16	8
PO_4-P	0.53	2.74	1.48	0.63	8
NO2	0.27	0.76	0.44	0.13	8
NO3	0.51	3.9	2.10125	0.8563167	8
Chlorophyll	0.17	0.51	0.31	0.08	8
Zoopl. biomass	1.01	11.06	3.14	4.02	8
Zoopl. density	54746.944	4225544.6	1453982.27	967384.38	8

Table-3.2.1 Range and Average of different parameters during May Low Tide at Surface.

Parameters	Min	Max	Average	SD	n
Temp.	30.27	30.83	0.18	30.63	9
Salinity	34.44	35.43	0.35	35.15	9
Turbidity	7.55	29.7	6.63	16.73	9
Suspended sediments	0.041	0.0691	0.06	0.01	6
DO	5.01	6.06	0.33	5.45	9
pH	7.79	7.95	0.07	7.87	9
Silicates	4.24	11.76	3.38	7.47	9
PO_4-P	0.53	2.74	0.65	1.41	9
NO2	0.29	0.76	0.14	0.46	9
NO3	0.51	3.9	2.0625	1.0931965	9
Chlorophyll	0.23	0.34	0.05	0.30	9
Zoopl. biomass	1.01	11.06	3.14	4.02	9
Zoopl. density	54746.944	4225544.6	1453982.27	967384.38	9

Table-3.2.2 Range and Average of different parameters during May Low Tide at Bottom.

Parameters	Min	Max	Average	SD	n
Temp.	30.34	30.78	0.13	30.61	9
Salinity	35.27	35.44	0.06	35.36	9
Turbidity	8.9	18.5	3.14	13.21	9
Suspended sediments	0.0341	0.0951	0.06	0.02	6
DO	4.9	5.78	0.35	5.43	9
pH	7.79	7.97	0.07	7.89	9
Silicates	4.65	12.98	2.50	9.67	9
PO_4-P	0.53	2.74	0.63	1.44	9
NO2	0.27	0.71	0.14	0.45	9
NO3	1.47	3.16	2.14	0.61	9
Chlorophyll	0.17	0.51	0.10	0.33	9
Zoopl. biomass	1.01	11.06	3.14	4.02	9
Zoopl. density	54746.944	4225544.6	1453982.27	967384.38	9

Table-3.3 Range and Average of different parameters during May Diurnal.

Parameters	Min	Max	Average	SD	n
Temp.	30.4	31.8	30.8125	0.40	8
Salinity	29.39	35.72	34.878	1.36	8
Turbidity	12.4	59.2	20.965	11.45	10
Suspended sediments	0.11	0.63	0.2925	0.14	7
DO	4.28	5.07	4.88	0.21	10
pH	7.69	7.99	7.864	0.08	10
Silicates	2.73	14.34	6.5295	3.92	10
PO_4-P	0.48	2.1	1.0375	0.37	10
NO2	0.04	1.24	0.6115	0.27	10
NO3	1.65	8.96	4.49	1.65	10.00
Chlorophyll	0.032	0.048	0.040	0.00	10
Zoopl. biomass	1.02	6.63	3.576	1.79	10
Zoopl. density	15275.74	154779.64	82062.020	40941.63	10

Table-3.3.1 Range and Average of different parameters during May Diurnal at Surface.

Parameters	Min	Max	Average	SD	n
Temp.	30.2	30.71	30.38	0.19	8
Salinity	34.13	35.44	35.09	0.46	8
Turbidity	12.4	29.6	16.75	5.76	10
Suspended sediments	0.0341	0.0451	0.04	0.00	7
DO	4.63	5.07	4.96	0.14	10
pH	7.99	7.69	7.84	0.09	10
Silicates	2.73	13.94	5.32	3.23	10
PO_4-P	0.48	1.22	0.88	0.24	10
NO2	0.31	0.82	0.53	0.27	10
NO3	1.65	6.2	4.493	1.331	10
Chlorophyll	0.17	0.63	0.38	0.16	10
Zoopl. biomass	1.02	6.63	3.58	1.79	10
Zoopl. density	15275.738	154779.64	82062.02	40941.63	10

Table-3.3.2 Range and Average of different parameters during May Diurnal at Bottom.

Parameters	Min	Max	Average	SD	n
Temp.	30.3	30.48	30.36	0.06	8
Salinity	35.44	35.46	35.44	0.01	8
Turbidity	12.8	59.2	25.18	14.29	10
Suspended sediments	0.032	0.048	0.04	0.01	7
DO	4.28	5.04	4.79	0.24	10
pH	7.79	7.95	7.88	0.06	10
Silicates	2.88	14.34	7.74	4.33	10
PO_4-P	0.72	1.55	1.19	0.42	10
NO2	0.36	1.24	0.70	0.26	10
NO3	2	8.96	4.49	2.00	10
Chlorophyll	0.11	0.28	0.21	0.05	10
Zoopl. biomass	1.02	6.63	3.58	1.79	10
Zoopl. density	15275.738	154779.64	82062.02	40941.63	10

Table-3.4 Range and Average of different parameters during June.

Parameters	Min	Max	Average	SD	n
Temp.	29	30	29.32	0.34	9
Salinity	18.9	33.16	24.09	4.89	9
Turbidity	10.3	63.5	20.31	16.77	9
Suspended sediments	0.0281	0.2141	0.06	0.06	7
DO	3.14	8.22	6.65	1.79	9
pH	7.82	8.37	8.03	0.16	9
Silicates	15.82	29.58	22.23	4.35	9
PO_4-P	0.16	2.54	0.59	0.65	9
NO2	0.17	1.14	0.44	0.23	9
NO3	0	3.680	0.683	1.091	9
Chlorophyll	0.4	1.93	1.05	0.42	9
Zoopl. biomass	2.59	38.61	11.86	11.95	9
Zoopl. density	16117.936	126886.89	51919.31	35866.87	9

Table-3.4.1 Range and Average of different parameters during June at Surface.

Parameters	Min	Max	Average	SD	n
Temp.	28.36	29.06	28.63	0.21	9
Salinity	19.32	22.62	21.17	0.99	9
Turbidity	7.38	13.4	11.06	2.00	9
Suspended sediments	0.0281	0.0401	0.03	0.00	7
DO	7.13	8.22	7.72	0.32	9
PHC	65.11	101.36	84.44	12.78	9
pH	7.9	8.37	8.10	0.17	9
Silicates	17.79	25.03	21.83	2.65	9
PO_4-P	0.16	0.58	0.33	0.15	9
NO2	0.19	0.68	0.38	0.16	9
NO3	0	0.48	0.1102	0.1591	9
Chlorophyll	0.63	1.93	1.26	0.47	9
Zoopl. biomass	2.59	38.61	11.86	11.95	9
Zoopl. density	16118	126887	51919	35867	9

Table-3.4.2 Range and Average of different parameters during June at Bottom.

Parameters	Min	Max	Average	SD	n
Temp.	28.47	28.59	28.54	0.04	9
Salinity	24.13	32	29.34	2.58	9
Turbidity	10.3	63.5	29.57	20.02	9
Suspended sediments	0.0491	0.0601	0.09	0.07	7
DO	3.14	8.1	5.58	2.04	9
PHC	66.75	93.74	81.64	12.55	9
pH	7.82	8.15	7.95	0.12	9
Silicates	15.82	29.58	22.63	5.73	9
PO_4-P	0.21	2.54	0.84	0.86	9
NO2	0.17	1.14	0.50	0.28	9
NO3	0	3.68	1.2844	1.2992	9
Chlorophyll	0.4	1.25	0.83	0.23	9
Zoopl. biomass	2.59	38.61	11.86	11.95	9
Zoopl. density	16118	126887	51919	35867	9

Table-4.1 Showing Univariate Diversity indices during May High Tide.

Sample	S	N	d	J'	H'(loge)	1-Lambda'
4	17	267240	1.28	0.3456	0.9792	0.5515
6	16	100790	1.302	0.3121	0.8653	0.5301
7	11	10738	1.077	0.5158	1.237	0.6387
9	12	170588	0.9131	0.3585	0.8907	0.5427
11	14	123652	1.109	0.3274	0.864	0.5318
12	16	85676	1.321	0.43	1.192	0.6115
14	13	35355	1.146	0.5145	1.32	0.6486
16	17	245762	1.289	0.2985	0.8456	0.5278
Total	116	1039801	9.4371	3.1024	8.1938	4.5827
Mean	14.5	129975.1	1.179638	0.3878	1.024225	0.5728375

S=no. of groups,N=Total population Density,d=Species richness
,J=Evenness,H=Shannon diversity index

Table-4.2 Showing Univariate Diversity indices during May Low Tide.

Sample	S	N	d	J'	H'(loge)	1-Lambda'
4	12	130848	0.9336	0.1454	0.3614	0.1348
6	10	156517	0.7525	0.1523	0.3506	0.1331
7	12	54706	1.008	0.1354	0.3365	0.1218
9	11	123799	0.8528	0.1749	0.4194	0.1604
11	12	101960	0.9538	0.1212	0.3013	0.1156
12	6	4216040	0.3278	0.109	0.1953	7.34E-02
14	10	1574651	0.6307	0.1715	0.3949	0.1505
16	11	1361338	0.708	0.1573	0.3772	0.1434
Total	84	7719859	6.1672	1.167	2.7366	1.033
Mean	10.5	964982.4	0.7709	0.145875	0.342075	0.129125

S=no. of groups,N=Total population Dencity,d=Species richness
,J=Evenness,H=Shannon diversity index

Table-4.3 Showing Univariate Diversity indices during May Diurnal.

Sample	S	N	d	J'	H'(loge)	1-Lambda'
1100	12	115741	0.9435	7.96E-02	0.1977	6.48E-02
1300	14	77910	1.154	0.131	0.3457	0.123
1500	12	75495	0.9794	9.25E-02	0.2299	7.35E-02
1700	10	59570	0.8186	6.76E-02	0.1556	5.04E-02
2100	13	119625	1.026	6.30E-02	0.1617	5.19E-02
2300	11	15276	1.038	0.2829	0.6784	0.3137
100	12	154780	0.9205	0.1361	0.3383	0.1265
300	11	51892	0.9211	0.1422	0.341	0.1154
700	15	99872	1.216	0.1986	0.5378	0.1953
1100	13	50459	1.108	0.1578	0.4049	0.1538
Total	123	820620	10.1251	1.35132	3.391	1.26839
Mean	22.36364	149203.6	1.840927	0.24569455	0.616545455	0.230616364

S=no. of groups,N=Total population Dencity,d=Species richness
,J=Evenness,H=Shannon diversity index

Table-4.4 Showing Univariate Diversity indices during June.

Sample	S	N	d	J'	H'(loge)	1-Lambda'
1	10	36819	0.856	0.458	1.054	0.5798
4	8	75741	0.623	0.4013	0.8344	0.5262
6	10	159950	0.7511	0.3716	0.8556	0.5301
7	6	147645	0.4201	0.5173	0.9269	0.5563
9	8	82197	0.6185	0.4304	0.895	0.5414
11	7	253774	0.4822	0.4028	0.7839	0.5158
12	10	52468	0.8281	0.3992	0.9192	0.5452
14	7	32236	0.578	0.4578	0.8908	0.5389
16	9	93717	0.6988	0.4609	1.013	0.5697
Total	75	934547	5.8558	3.8993	8.1728	4.9034
Mean	15	186909.4	1.17116	0.77986	1.63456	0.98068

S=no. of groups,N=Total population Dencity,d=Species richness
,J=Evenness,H=Shannon diversity index

PRIMER 26/10/2004

Draftsman Plot
Scatter plots for variable pairs

Worksheet
File: Results of the file May High Tide Low Tide Bottom.xls
Sample selection: All
Variable selection: All

Variable	Variable	Correlation
Turbidity	H'(loge)	0.506
Turbidity	Biomass	-0.190
Turbidity	logsDEN	-0.325
Turbidity	Salinity	-0.210
Turbidity	Temp (0C)	-0.600
Turbidity	DO.(mg/l)	-0.381
Turbidity	pH	0.042
Turbidity	Chloro.	-0.278
Turbidity	NO2	-0.335
Turbidity	NO3	0.605
Turbidity	PO4-P	0.505
Turbidity	F Eggs and Lar.	-0.242
H'(loge)	Biomass	0.008
H'(loge)	logsDEN	-0.507
H'(loge)	Salinity	-0.193
H'(loge)	Temp (0C)	-0.572
H'(loge)	DO.(mg/l)	-0.291
H'(loge)	pH	-0.018
H'(loge)	Chloro.	-0.150
H'(loge)	NO2	-0.452
H'(loge)	NO3	0.362
H'(loge)	PO4-P	-0.014
H'(loge)	F Eggs and Lar.	-0.289
Biomass	logsDEN	0.336
Biomass	Salinity	0.054
Biomass	Temp (0C)	0.220
Biomass	DO.(mg/l)	0.280
Biomass	pH	0.197
Biomass	Chloro.	0.192
Biomass	NO2	-0.118
Biomass	NO3	-0.148
Biomass	PO4-P	-0.310
Biomass	F Eggs and Lar.	0.189
logsDEN	Salinity	-0.398
logsDEN	Temp (0C)	0.596

File: May High Tide Low Tide Bottom.xls (Continued)

Variable	Variable	Correlation
logsDEN	DO.(mg/l)	0.706
logsDEN	pH	-0.007
logsDEN	Chloro.	0.497
logsDEN	NO2	0.021
logsDEN	NO3	-0.530
logsDEN	PO4-P	0.330
logsDEN	F Eggs and Lar.	0.815
Salinity	Temp (0C)	-0.078
Salinity	DO.(mg/l)	-0.485
Salinity	pH	-0.104
Salinity	Chloro.	-0.290
Salinity	NO2	0.303
Salinity	NO3	0.105
Salinity	PO4-P	-0.594
Salinity	F Eggs and Lar.	-0.365
Temp (0C)	DO.(mg/l)	0.615
Temp (0C)	pH	-0.004
Temp (0C)	Chloro.	0.280
Temp (0C)	NO2	0.123
Temp (0C)	NO3	-0.509
Temp (0C)	PO4-P	0.061
Temp (0C)	F Eggs and Lar.	0.415
DO.(mg/l)	pH	-0.034
DO.(mg/l)	Chloro.	0.196
DO.(mg/l)	NO2	-0.076
DO.(mg/l)	NO3	-0.416
DO.(mg/l)	PO4-P	0.163
DO.(mg/l)	F Eggs and Lar.	0.583
pH	Chloro.	-0.083
pH	NO2	0.003
pH	NO3	0.187
pH	PO4-P	-0.040
pH	F Eggs and Lar.	-0.168
Chloro.	NO2	-0.227
Chloro.	NO3	-0.169
Chloro.	PO4-P	0.068
Chloro.	F Eggs and Lar.	0.491
NO2	NO3	-0.351
NO2	PO4-P	-0.112
NO2	F Eggs and Lar.	0.038
NO3	PO4-P	0.020
NO3	F Eggs and Lar.	-0.250
PO4-P	F Eggs and Lar.	0.305

Outputs
Plot: Plot1

PRIMER 26/10/2004

Draftsman Plot
Scatter plots for variable pairs

Worksheet
File: May Diurnal Bottom
Sample selection: All
Variable selection: All

Variable	Variable	Correlation
Turbidity	Biomass	-0.036
Turbidity	H'(loge)	0.073
Turbidity	logsDN	-0.263
Turbidity	Salinity	0.088
Turbidity	Temp	0.439
Turbidity	DO	0.342
Turbidity	pH	0.652
Turbidity	Chloro.	-0.211
Turbidity	NO2	-0.616
Turbidity	NO3	0.917
Turbidity	PO4-P	0.150
Turbidity	F Eggs and Lar.	0.046
Biomass	H'(loge)	-0.120
Biomass	logsDN	0.481
Biomass	Salinity	-0.148
Biomass	Temp	-0.163
Biomass	DO	0.503
Biomass	pH	0.528
Biomass	Chloro.	0.217
Biomass	NO2	-0.020
Biomass	NO3	0.075
Biomass	PO4-P	0.226
Biomass	F Eggs and Lar.	0.165
H'(loge)	logsDN	0.401
H'(loge)	Salinity	0.351
H'(loge)	Temp	-0.015
H'(loge)	DO	-0.558
H'(loge)	pH	-0.207
H'(loge)	Chloro.	0.281
H'(loge)	NO2	-0.240
H'(loge)	NO3	-0.007
H'(loge)	PO4-P	-0.181
H'(loge)	F Eggs and Lar.	0.271
logsDN	Salinity	0.383
logsDN	Temp	-0.083
logsDN	DO	0.020
logsDN	pH	0.139

File: May Diurnal Bottom (Continued)

Variable	Variable	Correlation
logsDN	Chloro.	0.004
logsDN	NO2	0.216
logsDN	NO3	-0.406
logsDN	PO4-P	-0.034
logsDN	F Eggs and Lar.	0.697
Salinity	Temp	-0.346
Salinity	DO	-0.234
Salinity	pH	-0.208
Salinity	Chloro.	-0.330
Salinity	NO2	-0.192
Salinity	NO3	-0.061
Salinity	PO4-P	-0.738
Salinity	F Eggs and Lar.	0.212
Temp	DO	0.254
Temp	pH	0.575
Temp	Chloro.	0.021
Temp	NO2	-0.243
Temp	NO3	0.461
Temp	PO4-P	0.505
Temp	F Eggs and Lar.	-0.075
DO	pH	0.811
DO	Chloro.	-0.134
DO	NO2	-0.367
DO	NO3	0.361
DO	PO4-P	0.581
DO	F Eggs and Lar.	-0.048
pH	Chloro.	0.012
pH	NO2	-0.488
pH	NO3	0.646
pH	PO4-P	0.538
pH	F Eggs and Lar.	0.112
Chloro.	NO2	-0.305
Chloro.	NO3	-0.154
Chloro.	PO4-P	0.012
Chloro.	F Eggs and Lar.	-0.140
NO2	NO3	-0.634
NO2	PO4-P	-0.051
NO2	F Eggs and Lar.	0.345
NO3	PO4-P	0.200
NO3	F Eggs and Lar.	-0.284
PO4-P	F Eggs and Lar.	0.028

Outputs

Plot: Plot1

PRIMER 26/10/2004

Draftsman Plot
Scatter plots for variable pairs

Worksheet

File: JUNE BOT.xls
Sample selection: All
Variable selection: All

Variable	Variable	Correlation
Turbidity	H'(loge)	0.006
Turbidity	Biomass	-0.574
Turbidity	logsDN	-0.556
Turbidity	Salinity	-0.010
Turbidity	Temp	-0.581
Turbidity	DO	-0.903
Turbidity	pH	-0.681
Turbidity	Chloro.	0.168
Turbidity	NO2	0.563
Turbidity	NO3	0.879
Turbidity	PO4-P	0.406
Turbidity	F Eggs and Lar.	0.104
H'(loge)	Biomass	-0.155
H'(loge)	logsDN	-0.289
H'(loge)	Salinity	0.402
H'(loge)	Temp	0.575
H'(loge)	DO	-0.164
H'(loge)	pH	-0.369
H'(loge)	Chloro.	-0.097
H'(loge)	NO2	-0.130
H'(loge)	NO3	0.211
H'(loge)	PO4-P	0.621
H'(loge)	F Eggs and Lar.	0.678
Biomass	logsDN	0.650
Biomass	Salinity	-0.150
Biomass	Temp	-0.087
Biomass	DO	0.713
Biomass	pH	0.473
Biomass	Chloro.	0.244
Biomass	NO2	-0.417
Biomass	NO3	-0.714
Biomass	PO4-P	-0.581
Biomass	F Eggs and Lar.	-0.467
logsDN	Salinity	-0.781
logsDN	Temp	-0.217

File: JUNE BOT.xls (Continued)

Variable	Variable	Correlation
logsDN	DO	0.412
logsDN	pH	0.261
logsDN	Chloro.	0.464
logsDN	NO2	-0.321
logsDN	NO3	-0.612
logsDN	PO4-P	-0.448
logsDN	F Eggs and Lar.	-0.286
Salinity	Temp	0.579
Salinity	DO	0.199
Salinity	pH	0.175
Salinity	Chloro.	-0.610
Salinity	NO2	-0.028
Salinity	NO3	0.072
Salinity	PO4-P	0.180
Salinity	F Eggs and Lar.	0.169
Temp	DO	0.410
Temp	pH	0.162
Temp	Chloro.	-0.348
Temp	NO2	-0.526
Temp	NO3	-0.224
Temp	PO4-P	0.351
Temp	F Eggs and Lar.	0.576
DO	pH	0.863
DO	Chloro.	-0.324
DO	NO2	-0.397
DO	NO3	-0.935
DO	PO4-P	-0.650
DO	F Eggs and Lar.	-0.417
pH	Chloro.	-0.628
pH	NO2	0.090
pH	NO3	-0.886
pH	PO4-P	-0.860
pH	F Eggs and Lar.	-0.703
Chloro.	NO2	-0.509
Chloro.	NO3	0.307
Chloro.	PO4-P	0.344
Chloro.	F Eggs and Lar.	0.301
NO2	NO3	0.203
NO2	PO4-P	-0.279
NO2	F Eggs and Lar.	-0.463
NO3	PO4-P	0.772
NO3	F Eggs and Lar.	0.541
PO4-P	F Eggs and Lar.	0.949

Outputs
Plot: Plot1